FRENCH LIMITED SITE
CROSBY, TEXAS

DNAPL Study
Risk Evaluation

Prepared for:

FLTG, Incorporated
Crosby, Texas

Submitted to.

U.S. Environmental Protection Agency
Region 6
Dallas, Texas

Prepared by:

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Denver, Colorado

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MEMORANDUM

Date: April 30, 1994

To: R. L. Sloan

From: M. J. Day

Subject:: Response to comments on French Limited DNAPL Draft Endangerment Assessment

This memo addresses specific comments made by CH_2M Hill (memo dated March 15, 1994 to Judith Black, EPA, from John McLeod and Alpheus Sloan of CH_2M Hill) on AHA's *Draft DNAPL Study Endangerment Assessment* dated December 1993 The memo addresses all the comments individually Each comment is reiterated with the reference location in the *Draft DNAPL Study Endangerment Assessment*, followed by a response to the comment and a reference to any changed text in the revised report document The revised document is titled *DNAPL Study Risk Evaluation* dated April 1994.

Summary Comments

Comment

1 *The document evaluates the risk posed by the "no-action" alternative for DNAPL remediation It assumes the ongoing aquifer remediation work is complete and the system is turned off. Groundwater modeling, using the known DNAPL areas as sources, is used to estimate the concentration at the identified exposure points. Heath risks are then estimated based upon assumed exposure pathways.*

Response

No response required

Comment

2. *The document generally follows the Work Plan and Agency guidance with the exception of the selection and justification of exposure points Three exposure points are assumed*

   - *Domestic wells at the Riverdale subdivision,*
   - *Surface exposure (swimming) at the South Pond and East slough,*
   - *Domestic wells south of new HWY-90*

   We disagree with the south of new HWY-90 exposure point Insufficient evidence has been presented to justify moving the exposure point from Gulf Pump Road to a point south of HWY-90. The assessment is based on the assumption that the property south of Gulf Pump Road will be subjected to institutional controls or deed restrictions and converted to wetlands, a condition that has not yet been decided

Response

We agree that, for a baseline risk evaluation, institutional controls should not be assumed. Accordingly, the nearest exposure point, north of Gulf Pump Road has been retained in the revised document Two exposure pathways have been added to Figure 3-2 of the revised Risk Evaluation These pathways include hypothetical domestic wells, located north of Gulf Pump Road, tapping the INT unit immediately south of the INT-11 Area and tapping the S1 unit south of the S1-13 Area No land use restrictions are assumed for this scenario

Comment

3. *The risk data presented in the assessment indicate that some type of remedial action of DNAPL areas will be required, but because of the choice of exposure points the time frame for implementing the remedial action may be underestimated Additional modeling using the current closest groundwater exposure point is recommended to clearly define the period when remediation is required.*

Response

The nearest exposure point, north of Gulf Pump Road has been retained in the revised document as described in the response to general comment 2 above Accordingly, the timing considerations associated with remedial action are now addressed

Specific Comments

Comment

1. *Page 1-4, third paragraph. The future exposure also assumes land use controls or restrictions that are presently not in force in the area with respect to the property south of Gulf Pump Road. The selection of the exposure point for future exposure in a baseline type of risk assessment cannot rely on institutional controls that are not presently in place The implementation of institutional controls would be considered a risk management remedial action and an alternative to be considered in a feasibility study not a baseline risk assessment.*

Response

We agree that the assumption of future land use controls and/or restrictions that would limit points of exposure south of Gulf Pump Road is inappropriate for a baseline risk assessment This scenario has been retained to demonstrate a possible exposure scenario under existing land use conditions but for the purposes of the revised risk evaluation we have not assumed that the required land use restrictions are in place. In addition, risk has been evaluated using a more intensive land use scenario that does not require land access restrictions This includes hypothetical domestic wells tapping both the INT and S1 units immediately north of Gulf Pump Road as the nearest points of exposure The appropriate sections of the revised report - Section 3.0, *Exposure Assessment,* Section 5 0 *Risk Characterization* and Appendix A - have been revised to include the additional potential exposure point north of Gulf Pump Road

Comment

2 *Page 2-7, Table 2-2. The table does not reference the source for the "French Ltd Cleanup Criteria".*

Response

The correct reference for the "French Ltd Cleanup Criteria" is now provided The source of these data is the *French Limited Site Remediation Quality Assurance Project Plan, December 1993,* and is referenced in the revised Table 3-2

Comment

3. Page 3-4, first paragraph, first line Please clarify what "will be" In the current syntax it seems to be a strong statement given that the exposure routes, points, concentrations, and rates are all hypothetical and may not ever happen.

Response

The term "will be" has been replaced with "may be" in the revised document to reflect uncertainty of future exposures

Comment

4 Page 3-6, fourth paragraph In the DNAPL Study Field Data Report dated November 1993, Figure 1-1 page 1-2 areas of "DNAPL Residual Zones" are shown that could be at a shallow enough depth to be considered a possible exposure route if someone were to excavate for a foundation for a building The argument eliminating this exposure pathway could be strengthened for example by discussion of current building practice in the area and the high groundwater levels which discourage construction of deep structures

Direct exposure to DNAPL and DNAPL-impacted soils was not evaluated as an exposure pathway in the Draft *DNAPL Study Endangerment Assessment* The rationale for excluding this pathway was the absence of a means of direct contact with DNAPL (exposure route) other than by trained workers during drilling and excavation activities associated with site investigations or remediation

Figure 1-1 of the *DNAPL Field Data Report* is conceptual in nature As indicated in this report, DNAPL-impacted strata have been observed at depths of no less than 27 feet At this depth, DNAPL could *potentially* be encountered during a future excavation for a building foundation However, the presence of a shallow water table discourages deep excavations The current local building practice is to install shallow concrete slabs to provide building support

Additional description of current building practices and water table conditions as justification for eliminating the direct contact exposure route has been added to Section 3 0 *Exposure Assessment* of the revised Risk Evaluation Report

Comment

5 *Page 3-7, Figure 3-2. The future exposure assuming land use controls or restrictions that are presently not in force in the area with respect to the property between Gulf Pump Road and new U.S HWY 90 is inappropriate The selection of the exposure point for future exposure in a baseline type of risk assessment cannot rely on institutional controls that are not presently in place The implementation of institutional controls would be considered a risk management remedial action and an alternative to be considered in a feasibility study not a baseline risk assessment.*

Response

See response to Specific Comment #1 Section 3 0 and Figure 3-2 of the final Risk Evaluation report has been revised to reflect the absence of any land use restrictions other than those which are currently in place.

Comment

6 *Page 3-13, last paragraph. The future exposure assuming land use controls or restrictions are presently not in force in the area with respect to the property between Gulf Pump Road and new U.S. HWY 90 is inappropriate The selection of the exposure point for future exposure in a baseline type of risk assessment cannot rely on institutional controls that are not presently in place. The implementation of institutional controls would be considered a risk management remedial action and an alternative to be considered in a feasibility study not a baseline risk assessment Until deed restrictions and institutional controls limiting the use of this area to "wetland/recreational" are in place, other more intensive land use must be assumed for potential exposure*

Response

See response to Specific Comment #1

Comment

7. Page 3-18, third paragraph, second sentence. Appendix A describes the source point concentrations as the maximum observed level in a well Is this the same a those values in Table 2-2?

Response

Initial chemical concentrations which were used as model input values, also defined as "source point concentrations" were defined in the *Draft DNAPL Study Endangerment Assessment* (Appendix A, page A-2, first paragraph, last sentence) For each chemical, the maximum observed groundwater concentration in each source area was used to calculate the chemical release rate

Table 2-2 of the *Draft DNAPL Study Endangerment Assessment* lists maximum observed concentrations for various compounds and media for the entire French limited site. Corrections have been made to this table to reflect more complete data sources than was originally reported. Concentrations used to calculate release rates for the model reflect local or relative maximum values for five individual compounds in each source area. An additional table, Table 2-3, has been added to the revised report to summarize the maximum groundwater concentrations in each of the four "source" areas.

For each of the exposure pathways considered in Section 3 0 , the appropriate maximum observed groundwater concentration in the corresponding source area was used to model the transport of modeled compounds to the receptor points The source concentrations summarized in the new Table 2-3 may be less than or equal to the groundwater maximum concentration listed in Table 2-2 The concentrations for any given compound would be equal in both Table 2-2 and 2-3 only if the maximum observed concentration for that compound *for the entire French Limited site* was encountered in a well in the vicinity of that source area In all other cases the model input value was derived from *a relative or local maximum concentration* which was less than the maximum observed at the site

It should be noted that Tables 2-2 and 2-3 include only data from locations outside the sheetpile cutoff wall This is because only DNAPL-impacted areas outside the wall are considered to be potential continuing sources of groundwater contamination after the existing remedial operations are terminated

Comment

8. Page 3-18, third paragraph, next to last sentence *The future exposure assuming land use controls or restrictions that are presently not in force in the area with respect to the property between Gulf Pump road and new U S HWY 90 is inappropriate. The selection of the exposure point for future exposure in a baseline type of risk assessment cannot rely on institutional controls that are not presently in place. The implementation of institutional controls would be considered a risk management remedial action and an alternative to be considered in a feasibility study not a baseline risk assessment. Until deed restrictions and institutional controls limiting the use of this area are in place, other more intensive land use must be assumed for potential exposure*

Response

See response to Specific Comment #1 This paragraph has been rewritten to reflect the absence of any land use restrictions of all exposure scenarios other than those which are currently in place

Comment

9 Page 3-19, first paragraph, Item No 2 *Should the contaminant come from the "eastern" not the "western" part?*

Response

The transport scenario of migration of contaminants from the S1-13, S1-16 and INT-11 areas of the French Limited site to an exposure point south of new Hwy 90 are indeed from the eastern part of the site and not the western part as stated This typographical error has been corrected in the revised *DNAPL Study Risk Evaluation Report.*

Comment

10. Page 3-19, second paragraph The modeling described in Appendix A discusses the evaluation of four compounds, how were the concentration for the remaining compounds presented in Table 3-4 calculated?

Response

Exposure concentrations for all of the chemicals listed in Table 3-4 were derived or directly obtained from the maximum groundwater concentrations observed at monitoring wells in each of the four source areas. This is because no attenuation processes were assumed in the transport modeling that would actually reduce contaminant mass Retardation processes, such as adsorption onto soils were included in the analysis but these processes have the effect of slowing the migration rate compared to that of groundwater. However, modeling confirms that, under these conservative attenuation assumptions, and if the source concentrations are maintained due to DNAPL occurrence, the maximum groundwater concentration at the exposure point will eventually equal that in the source area The time when these concentrations are realized for different constituents varies depending on the retardation characteristics for each constituent as noted in Appendix A

The only processes that will change the maximum exposure concentration, under these assumptions, is dilution from less contaminated water sources or a mass transfer to another media For example, dilution will occur in the case of the surface water exposure scenarios where contaminated groundwater discharge is assumed to mix with uncontaminated surface waters Mass transfer effects will influence exposure concentrations in the cases of calculated exposure to vapor concentrations during showering with a contaminated groundwater supply and ingestion of fish caught in ponds affected by contaminated groundwater discharge The concentrations for each chemical differ between the various exposure pathways, due to dilution or mass transfer calculations required to convert the initial groundwater concentration to other media (i e groundwater vapor, pond water, or ingested biomass)

Accordingly, the four compounds chosen for modeling in the Draft report were selected on the basis of prevalence in the source areas and to give a range of expected migration transport times for the various scenarios. The explanation of this choice was not included in the Draft report The revised report has included an explanation of the rational for modeling only a selected number of constituents Also, acetone (the most mobile or least retarded constituent) was included to the constituents modeled so that the range of migration times was more fully covered for each of the pathways examined

The exposure concentrations for each of the exposure pathways were derived as follows:

Groundwater	Maximum detected groundwater concentration from each source area These values are listed in Table 2-3 of the revised report
Groundwater vapor	Maximum detected groundwater concentration from each source area, listed in Table 2-3, converted to the vapor phase using the mass transfer calculations shown in Appendix B of the revised report
Surface Water	Maximum detected concentration from each source area, listed in Table 2-3, diluted to the surface water concentration using the loading rates and dilution factors shown in Table A-2 of Appendix A of the revised report
Fish	Fish biomass concentration obtained by multiplying the calculated surface water concentration by the Biomass Concentration Factor (BCF) for each constituent as shown in Tables 3-2 and 3-4 of the revised report

Comment

11. Page 3-25, second paragraph *See comments on page 3-6*

Response

This item is addressed on page 3-6 of the revised *DNAPL Study Risk Evaluation* and is described in the response to Comment 4

Comment

12. Page 3-25, last paragraph. The majority of the DNAPL contaminants of concern seem to be volatiles and can migrate in the unsaturated zone as vapors and could collect in subsurface structures such as basements. Because of the current building practices and high groundwater levels this pathway may not be probable but there should be some consideration for this pathway from at least a qualitative perspective.

Response

As addressed in the response to Comment 4, the high water table conditions in the floodplain of the San Jacinto River discourage the construction of subsurface structures, including basements Accordingly, the accumulation of volatile organic vapors in such structures is not considered in the *DNAPL Study Risk Evaluation*, but is discussed in more detail on page 3-6 of the revised report

Comment

13. Page 3-26, next to last paragraph. The last sentence refers to the term "time frame" which is not referenced in the Appendix B If the author intended to refer to exposure duration, the phrase should be clarified.

Response

The term "time frame" has been replaced with the correct term "exposure duration" in the revised report for the purpose of clarification

Comment

14 Page 3-27, Table 3-5 The rationale for using 70 years for the exposure duration is not given. Typical exposure durations of 30 years, for the 90th percentile in one residence, is used in residential situations. This should be explained

Response

The exposure calculations have been re-evaluated using a 30 year exposure duration to be consistent with recommended values published in *Risk Assessment Guidance for Superfund Volume I Human Health Evaluation Manual Supplemental Guidance "Standard Default Exposure Factors"* by the USEPA The 30 year exposure duration is the 90th percentile for time spent at one residence for an adult

The 70 year exposure duration used in the original report was selected to account for a Reasonable Maximum Exposure (RME) of an individual who lived their entire life at either one location or in the same neighborhood This exposure duration was selected as a conservative assumption rather than being based upon documented site-specific data. Without the support of such data, the EPA guidance documents suggest that the standard default exposure factors be used

Comment

15. Page 3-28, Table 3-5 (continued) The rationale for using 70 years for the exposure duration for fish ingestion is not given. Typical exposure durations of 30 years, for the 90th percentile in one residence, is used in residential situation. This should be explained.

Response

The fish ingestion pathway has been re-evaluated using a 30 year exposure duration (the 90th percentile for time spent at one residence for an adult) to reflect values published in *Risk Assessment Guidance for Superfund Volume I Human Health Evaluation Manual Supplemental Guidance "Standard Default Exposure Factors"* by the USEPA.

Once again, the 70 year exposure duration used in the draft report was selected to account for a Reasonable Maximum Exposure (RME) of an individual who lived their entire life at either one location or in the same neighborhood

Comment

16. Page 3-29, third paragraph The rationale for using 70 years for the exposure duration for fish ingestion is not given Typical exposure durations of 30 years, for the 90th percentile in one residence, is used in residential situations This should be explained.

Response

The fish ingestion pathway has been re-evaluated using a 30 year exposure duration (the 90th percentile for time spent at one residence for an adult) to reflect values published in *Risk Assessment Guidance for Superfund Volume I Human Health Evaluation Manual Supplemental Guidance "Standard Default Exposure Factors"* by the USEPA.

Comment

17 Page 4-1, footnote. This footnote eliminates arsenic as a chemical of concern yet it is carried on to the toxicity screening discussion summarized in Table 4-5. If the background concentration for any inorganic has been established by using upgradient and or residential wells the information should be presented and then used to eliminate arsenic, or other inorganics, from the list of contaminants of concern

Response

This footnote was included to indicate the background arsenic concentrations in groundwater in the vicinity of the French Limited Site (approximately 0 to 20 micrograms/liter). Both wells FLTG-4 and FLTG-13 are outside DNAPL-impacted areas and are believed to represent maximum background levels of arsenic. The maximum concentration of arsenic detected in groundwater in the DNAPL-impacted areas was slightly above this level, up to a maximum of 103 micrograms/liter as indicated in Table 2-2 and 2-3 of the revised report. A lack of a direct comparison of these values in the original report, and the wording of the referenced footnote, suggested that arsenic could be removed as a chemical of concern in the risk assessment screening because it is present at close to background concentrations The footnote wording has been revised and additional explanation has been added to the text to remove this ambiguity Despite observed groundwater concentrations that are only slightly elevated above background values, arsenic is retained in the carcinogenic and noncancer toxicity assessment in the revised report because of the relative risks it contributes

Comment

18. Page 4-2, last paragraph The paragraph references 1992 EPA information but Table 4-6 relies on 1993 EPA information Why does one part of the same section rely on older information than the other? The paragraph says that there is no IRIS slope factor for vinyl chloride and tetrachloethene yet Table 4-6 has IRIS 1993 as a source for the slope factors that this paragraph says do not exist

Response

Tables 4-6 and 4-7 incorrectly referenced the 1993 edition of the HEAST rather than the 1992 edition which was the actual data source for some compounds in the draft report However, for the revised *DNAPL Study Risk Evaluation* Report, a updated review of toxicity data in IRIS was made on April 25, 1994 In addition, the latest available HEAST manual updates (HEAST Annual Update, March, 1993 and Supplement No 1 issued July, 1993) were reviewed for data not available in

IRIS. The tables listing toxicity data in the revised report, Tables 4-2, 4-6 and 4-7, reflect this latest review of available data. The reference document for toxicological data that is not available on IRIS is now HEAST, 1993 except for two constituents, trichloroethene (TCE) and tetrachloroethene (PCE). The 1990 edition of the HEAST was consulted to determine slope factors for these chemicals (and RfD for PCE) because values were under review at the time of the publication of the 1993 HEAST. The revised tables show the corrected references where appropriate and are now consistent

The last paragraph of page 4-2 of the *Draft DNAPL Study Endangerment Assessment,* correctly states that there was no verified slope factors or reference doses available for vinyl chloride, 1,1-dichloroethane, trichloroethene, tetrachloroethene (PCE), and naphthalene Tables 4-2, 4-6 and 4-7 of the revised report have been corrected to reflect the source documents for non-verified toxicological data for these constituents

The oral reference doses, and the oral and inhalation slope factors for tetrachloroethene (PCE) listed in Tables 4-2 and 4-6 were obtained from the HEAST, 1990 (as indicated above) While there were no *noncarcinogenic* toxicity values available for vinyl chloride from the IRIS or HEAST, 1993, *carcinogenic* toxicity oral reference doses and inhalation reference concentrations for vinyl chloride were obtained from the HEAST 1993 and are shown in the revised Tables 4-2 and 4-7. These values are the same as that used in the draft report which were actually obtained from HEAST, 1992 Also note that where "NA" was shown in either of these tables, a corresponding note was referenced indicating that no verified slope factors or reference doses were available

Comment

19. Page 4-5, Table 4-2 Some of the values and reference dates in this table differ from those given in Tables 4-6 and 4-7, (For example compare 1,1,2 TCA and vinyl chloride) Which tables should be considered to be accurate?

Response

As indicated in the response to Comment 18, Tables 4-6 and 4-7 incorrectly referenced the 1993 edition of the HEAST rather than the 1992 edition which was the actual data source for some compounds in the draft report. For the revised *DNAPL Study Risk Evaluation* Report, a updated review of toxicity data in IRIS was made on April 25, 1994. In addition, the latest available HEAST manual updates (HEAST Annual Update, March, 1993 and Supplement No 1 issued July, 1993) were reviewed for data not available in IRIS The tables listing toxicity data in the revised report, Tables 4-2, 4-6 and 4-7, reflect this latest review of available data These tables show the corrected references where appropriate and are now

consistent. The reference document for toxicological data that is not available on IRIS is now HEAST, 1993, except for two constituents, TCE and PCE. The 1990 edition of the HEAST was consulted to determine slope factors for these chemicals (and RfD for PCE) because they were under review at the time of the publication of the 1993 HEAST. Discrepancies between toxicity values, reference sources, and reference dates in Tables 4-2, 4-6, and 4-7 have been corrected

Minor discrepancies between oral and inhalation slope factors for 1,1,2-trichloroethane (1,1,2-TCA) and vinyl chloride listed in Tables 4-2 and 4-7 have been corrected and are now current and consistent

Comment

20. Page 4-16, fourth paragraph *See comments on page 3-6*

Response

See response to comment 4. The route of exposure via direct DNAPL contact is discussed in the context of drilling, excavations, and local current building practices in the revised Sections 3 0 and 4 0.

Comment

21. Page 4-17, second paragraph, and Table 4-4 *The Table pares down the number of potential carcinogens from 17 to 9 using the "1% rule", Because the volatile compounds trichloroethene and 1,1,2-trichloroethane contribute less than 1% of the total risk it is valid to eliminate them from further consideration. In an evaluation of treatment alternatives for volatiles these low percentage compounds would be removed.*

This, however, does not hold true for the semivolatiles hexachlorobutadiene and hexachlorobenzene. Even though those two semivolatiles do not make the 1% risk contribution cutoff the treatment of them in the analysis of treatment alternatives in a feasibility study may affect the selection of a preferred alternative The author should evaluate if this could adversely effect future treatment decisions

Arsenic is retained during the screening, yet the text (footnote 1, page 4-1) alludes to it being at background concentration levels See Page 4-1 comment

Response

As explained in section 4 6.1, page 4-17 of the draft report, any compound with a Noncancer Hazard Quotient of 1 0 or greater (as shown in Table 4-4) was retained for further fate and transport screening. Only one semivolatile, hexachloroethane, met this criteria, but it was subsequently eliminated from further consideration because of its limited occurrence and transport in soil and groundwater, low Noncancer Hazard Quotient relative to the volatile constituents, and insignificant contribution to overall risk

Even though the standard toxicity and/or fate and transport criteria are not met, it may be reasonable to retain some semivolatile compound in the toxicity screening on the basis of the implications of the future selection of remediation alternatives However, retaining these compounds on the basis of possible future treatment ramifications rather than on the basis of risk goes beyond the guidelines of a baseline risk assessment

In the revised report, a more complete evaluation of source concentrations appropriate to the risk evaluation was made In particular, the latest available data from the 1993 annual sampling was included in the database and source concentrations were only considered for areas outside the sheetpile cutoff wall This because only areas outside the sheetpile cutoff wall are considered as potential future source areas for groundwater contamination In this revised analysis, both hexachlorobenzene and hexachlorobutadiene were not detected in groundwater of the four potential DNAPL-impacted "source" areas

Comment

22. Page 4-21, Table 4-5 See comment on page 4-17

Response

Arsenic was retained as a chemical of concern on the basis of both its carcinogenic and noncancer risk. The text of the footnote on page 4-1 has been rewritten to indicate that arsenic was detected in groundwater from DNAPL-impacted areas at concentrations which are slightly above background levels

Comment

23. Page 4-22, partial paragraph at top of page *See comment on page 3-6*

Response

See response to comment 4. The route of exposure via direct DNAPL contact is discussed in the context of drilling, excavations, and local current building practices in the revised Sections 3 0 and 4 0

Comment

24 Page 4-23, Table 4-6 *See comments on page 4-5 The nomenclature in this table differs from all others in the report On the first page should the acronym for 1,2-DCE be assumed to be trans?*

Response

Discrepancies between toxicity values, reference sources, and reference dates listed in Tables 4-2, 4-6, and 4-7 have been corrected and are addressed in items 18 and 19 of this reply to comments

The 1,2-DCE listed on the first page of Table 4-6 is for trans-1,2 DCE The concentration values listed on Tables 2-2 and 2-3 are for "total 1,2 DCE (i e the sum of both trans- and cis- isomers) as this is the current analytical protocol For risk assessment purposes, however, the total 1,2 DCE value is assumed to be trans-1,2 DCE The trans-1,2 DCE isomer toxicity values were chosen for risk evaluation because the carcinogenic values are listed in IRIS and are consequently the most up-to-date and accepted values for this type of analysis The cis-1,2 DCE toxicity information, derived from HEAST, 1993, is also presented in Tables 4-2 and 4-3 of the revised report for comparison However, only the trans-1,2 DCE values are used for the Risk Evaluation in Section 5 0

Comment

25. Page 4-25, Table 4-7 *See comments on page 4-5.*

Response

As indicated in the response to comment 18, discrepancies between toxicity values, reference sources, and reference dates listed in Tables 4-2, 4-6, and 4-7 have been corrected

Comment

26. Page 4-28, first paragraph It is unclear where are the sources for the toxicity data. The statements in this paragraph seem to disagree with the information and sources cited in table 4-6 and 4-7. For example, 1,1-DCE is listed in the table 4-7 as IRIS 1993, yet paragraph says toxicity data is not available. Please review these citations.

Response

As indicated in the response to comment 18, discrepancies between toxicity values, reference sources and dates listed in Tables 4-2, 4-6, and 4-7 have been corrected.

Comment

27 Page 5-3, third sentence. The sentences states "ten" carcinogenic chemical were evaluated. Table 4-5 list nine. Please clarify.

Response

The sentence incorrectly states that ten potential carcinogenic chemicals of concern were evaluated Nine such compounds were evaluated In the revised report, the list of chemicals of concern has been expanded slightly to include trichloroethene (TCE) and chromium Eleven of the revised list of fifteen chemicals of concern are carcinogenic.

Comment

28 Page 5-4, Table 5-1 The risks presented at this exposure point assume that deed restrictions and institutional controls are already in place The risks and time for first detection should be calculated for an exposure point immediately south of Gulf Pump Road

Please define the data columns MAX GW Conc at Exposure Pt , "Exposure Concentration" and "Time for First Detection".

Response

As indicated in the response to comment 1, the revised Risk Evaluation includes hypothetical domestic wells immediately north of Gulf Pump Road adjacent to the INT-11 and S1-13 "source" areas, as the nearest points of exposure Footnotes

have been added to the end of Tables 5-1 to 5-7 of the revised report to explain the column header abbreviations

Comment

29. Page 5-8, first paragraph The statement that the INT unit supplies only 10% of the well yield is probably true but additional data should be included to substantiate this claim. The next sentences states that the risks are probably overestimated by 10 times in only true if the INT unit will not supply enough water for a resident to use.

Response

The *March, 1994, French Ltd. Project Monthly Progress Report* indicates that the average groundwater production for the month was 2 93 gallons/minute from 47 wells screened in the S1 unit and 0 87 gallons/minute from 50 wells screened in the INT unit. These relative rates of groundwater pumping suggests that while well yield vary in both units, INT unit wells yield roughly 30% the production of S1 wells at the site (rather than the 10% that was suggested in the DNAPL Study Endangerment Assessment)

Wells in the Riverdale subdivision which penetrate only the shallow alluvial sediments (to depths less than 100 feet) are typically screened through both the S1 and INT units The relative yield of the S1 and INT units to such a well may be reasonably estimated by examining the relative yields of S1 (70% of the total) and INT (30% of the total) production wells at the French Limited site Given that this is a reasonable estimate, it follows that the calculated risk associated with consumption of groundwater from a Riverdale well is probably exaggerated by about 70% (than for a well which taps only the INT unit) A well screened only in the INT unit which yields less than a gallon a minute may be adequate for small domestic supply. However, it is unlikely that such wells exist in Riverdale because the higher yielding S1 unit occurs at a shallower depth and wells drilled to the depths of the INT are screened through both the S1 and INT to obtain a maximum yield

The intake values and subsequent risk calculations for the Riverdale exposure scenarios assume 100% contribution from the INT unit The more probable 30% contribution of the INT unit is discussed in the section on "Uncertainty", and the 30% value is supported by production data from the French Limited site remedial system as indicated above

Comment

30 Page 5-19, fifth paragraph. See comment on page 5-8

Response

The relative yields and the implications of the associated risk are discussed in the response to comment 29

Comment

31. Page 5-26, first paragraph The conclusions presented are supported by the data presented The information not presented such as the assumed exposure points and the time of first unacceptable risk concentrations leave questions as to when and where the needed remediation will take place

Response

The exposure points and pathways in the final report have been revised to include points of exposure north of Gulf Pump Road and a more complete discussion of timing issues that have a direct influence on potential remedial actions Additional discussion has been added to the conclusions to emphasize the need for expeditious remedial action to address the excavation, treatment, or containment of the DNAPL impacted areas which continue to contaminate groundwater. The evaluation of specific remedial action is addressed in the *DNAPL Study, Remedial Alternative Selection and Feasibility Study Report, December 1993* It is important to note, as stated in the report, that migration of DNAPL-contaminated groundwater to the Riverdale subdivision is currently prevented by the hydraulic capture zone of the French Limited groundwater remedial system

Comment

32. Page A-1, first paragraph Please explain why the four compounds modeled were selected and the basis for calculating the concentration of the remaining compounds under consideration

Response

In the draft report, four compounds were selected for modeling solute transport, 1,2-DCA, chloroform, vinyl chloride, and benzene These compounds were selected to represent the bulk of the 13 chemicals of concern They are some of the most prevalent chemicals in French Limited groundwater and cover the range of

constituent mobility in groundwater (Koc's of 14, 31, 57, & 83 respectively based upon values listed in Table 3-2) Given this criteria, and the fact that a primary objective of the modeling was to determine the arrival of the bulk of the chemicals of concern, a modeling simulation of the transport of the most mobile chemical, acetone (Koc = 2 2), has been added to the revised *DNAPL Study Risk Evaluation* to account for the first arrival of a chemical of concern to the various receptors

Chemical concentrations of all of the compounds included in the various exposure scenarios (maximum groundwater concentration at exposure point) were derived from the local maximum concentrations for each chemical in the respective source area for each pathway considered A new table, Table 2-3, has been added to the final report to differentiate the groundwater concentrations for each chemical in the four "source" areas These concentrations are less than or equal to the maximum groundwater concentrations detected at the entire French Limited Site as listed in Table 2-2 and as explained in the response to comment 7 For each pathway, the arrival times for the chemicals of concern that were not specifically modeled, were extrapolated from the results of the five modeled chemicals on the basis of retardation factor ratios.

Comment

33. Page A-1, last paragraph The methodology for derivation of the retardation coefficients should be discussed in greater detail

Response

Retardation factors were calculated by the AT123D model, from the standard retardation equation (Freeze & Cherry, 1979)

$$R = 1 + (\rho_b/n) * Kd$$

where.

- R = the retardation factor,
- ρ_b = the bulk density of the media,
- n = the porosity of the media, and
- Kd = the distribution coefficient of the chemical

The variables ρ_b, n, and Kd are entered as model input and the source of each is explained in Appendix A . Because bulk density and porosity are considered to be constants for a given media, the distribution coefficient is the input parameter that most affects chemical retardation The derivation of the distribution coefficients is described on page A-2 of Appendix A

Appendix A emphasizes the influence of retardation factors upon the modeling results. In the AT123D model, retardation factors are *calculated* by the model using the retardation equation, rather than entered as model input as the last paragraph of page A-1 indicates. The values reported in Appendix A were actually calculated independent of the model, using the same retardation equation The reported values differ slightly from those calculated by the model because a single constant was assumed for the value of (ρ_b/n) to simplify the independent calculations. Retardation factors were provided to illustrate the relative transport properties of the four modeled chemicals and they should have been discussed in the context of modeling results rather than model input

Portions of Appendix A have been rewritten to clarify the importance of the distribution coefficients as input parameters and discuss the model-calculated retardation factors in the context of the modeling results

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DEFINITIONS

Absorbed Dose. The amount of a substance penetrating the exchange boundaries of an organism after contact. Absorbed dose is calculated from the intake and the absorption efficiency. It usually is expressed as mass of a substance absorbed into the body per unit body weight per unit time (e.g., mg/kg-day).

Administered Dose. The mass of a substance given to an organism and in contact with an exchange boundary (e.g., gastrointestinal tract) per unit body weight per unit time (e.g., mg/kg-day).

Applied Dose. The amount of a substance given to an organism, especially through dermal contact.

Chronic Daily Intake (CDI). Exposure expressed as mass of a substance contacted per unit body weight per unit time, averaged over a long period of time (as a Superfund program guideline, seven years to a lifetime).

Chronic Reference Dose (RfD). An estimate (with uncertainty spanning perhaps an order of magnitude or greater) of a daily exposure level for the human population, including sensitive subpopulations, that is likely to be without an appreciable risk of deleterious effects during a lifetime. Chronic RfDs are specifically developed to be protective for long-term exposure to a compound (as a Superfund program guideline, seven years to lifetime).

Contact Rate. Amount of medium (e.g., ground water, soil) contacted per unit time or event (e.g., liters of water ingested per day).

Exposure. Contact of an organism with a chemical or physical agent. Exposure is quantified as the amount of the agent available at the exchange boundaries of the organism (e.g., skin, lungs, gut) and available for absorption.

Exposure Assessment. The determination or estimation (qualitative or quantitative) of the magnitude, frequency, duration, and route of exposure

Exposure Event. An incident of contact with a chemical or physical agent. An exposure event can be defined by time (e.g., day, hour) or by the incident (e.g., eating a single meal of contaminated fish).

DEFINITIONS (Cont.)

Exposure Pathway. The course of a chemical or physical agent from a source to an exposed organism. An exposure pathway describes a unique mechanism by which an individual or population is exposed to chemicals or physical agents at or originating from a site. Each exposure pathway includes a source or release from a source, an exposure point, and an exposure route. If the exposure point differs from the source, one or more transport/exposure media (e.g., air, ground water) are included.

Exposure Point. A location of potential contact between an organism and a chemical or physical agent.

Exposure Route. The way a chemical or physical agent comes in contact with an organism (i.e., by ingestion, inhalation, dermal contact).

Hazard Identification. The process of determining whether exposure to an agent can cause an increase in the incidence of a particular adverse health effect (e.g., cancer, birth defect) and whether the adverse health effect is likely to occur in humans.

Hazard Index (HI). The sum of more than one hazard quotient for multiple substances and/or multiple exposure pathways. The HI is calculated separately for chronic, subchronic, and shorter-duration exposures.

Hazard Quotient. The ratio of a single substance exposure level over a specified time period (e.g., subchronic) to a reference dose for that substance derived from a similar exposure period.

Intake. A measure of exposure expressed as the mass of a substance in contact with the exchange boundary per unit body weight per unit time (e.g., mg chemical/kg-day). Also termed the normalized exposure rate; equivalent to administered dose.

Integrated Risk Information System (IRIS). An EPA data base containing verified RfDs and slope factors and up-to-date health risk and EPA regulatory information for numerous chemicals. IRIS is EPA's preferred source for toxicity information for Superfund.

Lifetime Average Daily Intake. Exposure expressed as mass of a substance contacted per unit body weight per unit time, averaged over a lifetime.

DEFINITIONS (Cont.)

Lowest-Observed-Adverse-Effect-Level (LOAEL). In dose-response experiments, the lowest exposure level at which there are statistically or biologically significant increases in frequency or severity of adverse effects between the exposure population and its appropriate control group.

No-Observed-Adverse-Effect-Level (NOAEL). In dose-response experiments, an exposure level at which there are no statistically or biologically significant increases in the frequency or severity of adverse effects between the exposure population and its appropriate control; some effects may be produced at this level, but they are not considered to be adverse, nor precursors to specific adverse effects. In an experiment with more than one NOAEL, the regulatory focus is primarily on the highest one, leading to the common usage of the term NOAEL to mean the highest exposure level without adverse effect.

No-Observed-Effect-Level (NOEL). In dose-response experiments, an exposure level at which there are no statistically or biologically significant increases in the frequency or severity of any effect between the exposure population and its appropriate control.

Reference Concentration (RfC). Chronic Reference Dose for inhalation exposure is generally reported as a concentration in air or Reference Concentration (RfC) in mg/m^3 for continuous 24 hour/day exposure.

Reference Dose (RfD). The EPA's preferred toxicity value for evaluating noncarcinogenic effects resulting from exposuresto chemicals. See specific entries for chronic RfD, and subchronic RfD. The acronym RfD, when used without other modifiers, either refers generically to all types of RfDs or specifically to chronic RfDs; it never refers specifically to subchronic or developmental RfDs.

Slope Factor. A plausible upper-bound estimate of the probability of a response per unit intake of a chemical over a lifetime. The slope factor is used to estimate an upper-bound probability of an individual developing cancer as a result of a lifetime of exposure to a particular level of a potential carcinogen.

Subchronic Daily Intake (SDI). Exposure expressed as mass of a substance contacted per unit body weight per unit time, averaged over a portion of a lifetime (2 weeks to 7 years).

DEFINITIONS (Cont.)

Subchronic Reference Dose (RfDs). An estimate (with uncertainty spanning perhaps an order of magnitude or greater) of a daily exposure level for the human population, including sensitive subpopulations, that is likely to be without an appreciable risk of deleterious effects during a portion of a lifetime (as a Superfund program guideline, two weeks to seven years).

Toxicity Value. A numerical expression of a substance's dose-response relationship that is used in risk assessments. The most common toxicity values used in Superfund program risk assessments are reference doses (for noncarcinogenic effects) and slope factors (for carcinogenic effects).

Weight-of-Evidence Classification. An EPA classification system for characterizing the extent to which the available data indicate that an agent is a human carcinogen. Recently, EPA has developed weight-of-evidence classification systems for some other kinds of toxic effects, such as developmental effects.

1.0 INTRODUCTION

This report presents the results of a Risk Evaluation (RE) of areas impacted by the occurrence of dense, non-aqueous phase liquid (DNAPL) at the French Limited site, Crosby, Texas. The RE follows the work plan (AHA, 1993a) approved by EPA in September, 1993. The report also incorporates EPA and CH_2M Hill review comments to a draft report submitted to EPA in December, 1993. The RE forms an integral part of an overall DNAPL investigation at the French Limited site. This included a field study of the nature and extent of DNAPL occurrence (AHA, 1993b) and the performance of a Feasibility Study (FS) of remedial options (AHA, 1994).

1.1 Regulatory Basis

The Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA or "Superfund") established a national program for responding to releases of hazardous substances into the environment[1]. The National Oil and Hazardous Substances Pollution Contingency Plan (NCP) is the regulation that implements CERCLA[2]. The NCP establishes the overall approach for determining appropriate remedial actions at Superfund sites. The overarching mandate of the program is to protect human health and the environment from current and potential threats posed by uncontrolled hazardous substance releases. The NCP reiterates that the purpose of the remedial process is to implement remedies that reduce, control, or eliminate risks to human health and the environment. The 1986 amendments to CERCLA[3] re-emphasized the original statutory mandate that remedies meet a threshold requirement to protect human health and the environment and that they be cost-effective, while adding new emphasis to the permanence of remedies.

To help meet this mandate, EPA's Office of Emergency and Remedial Response developed a human health and environmental evaluation process as part of its remedial response program. The process of gathering and assessing human health and environmental risk information is adapted from well-established chemical risk assessment principles and procedures (NAS 1983; CRS 1983; OSTP 1985). This Risk Evaluation is performed in accordance with an approved work plan (AHA, 1993a) that was developed to be consistent with EPA's most recent published risk evaluation guidelines (EPA 1988c; EPA 1989c; EPA 1990, EPA 1991a-c; EPA 1992a-c) and other Agency-wide risk evaluation policy. The *Human Health Evaluation Manual* (EPA 1989c and EPA 1991a-c) and the *Environmental Evaluation Manual* (EPA 1989e) were the major guidance documents for this work.

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1 References made to CERCLA throughout this document should be interpreted as meaning "CERCLA, as amended by the Superfund Amendments and Reauthorization Act of 1986 (SARA)"

2 40 CFR Part 300 Proposed Revisions to the NCP were published on December 21, 1988 (53 Federal Register 51394)

3 Superfund Amendments and Reauthorization Act or SARA

1.2 Objectives

The objective of this Risk Evaluation is to provide the risk information necessary to assist decision-making for remediation of DNAPL-impacted areas of the French Limited site. Specific objectives of the process are to:

- provide an analysis of baseline risks[4] and help determine the need for action at the DNAPL-impacted areas of the French Limited site;
- provide a basis for determining levels of chemicals that can remain on-site and still be adequately protective of public health;
- provide a basis for comparing potential health impacts of various remedial alternatives;
- provide a consistent process for evaluating and documenting public health threats from the DNAPL-impacted areas of the French Limited site.

1.3 Overview of Risk Evaluation Process

The risk evaluation (RE) for DNAPL-impacted areas of the French Limited site follows the four basic steps of the process specified in the work plan (Figure 1 1):

1. data collection and analysis;
2. exposure assessment;
3. toxicity assessment;
4. risk characterization.

These steps are briefly described in the following sections.

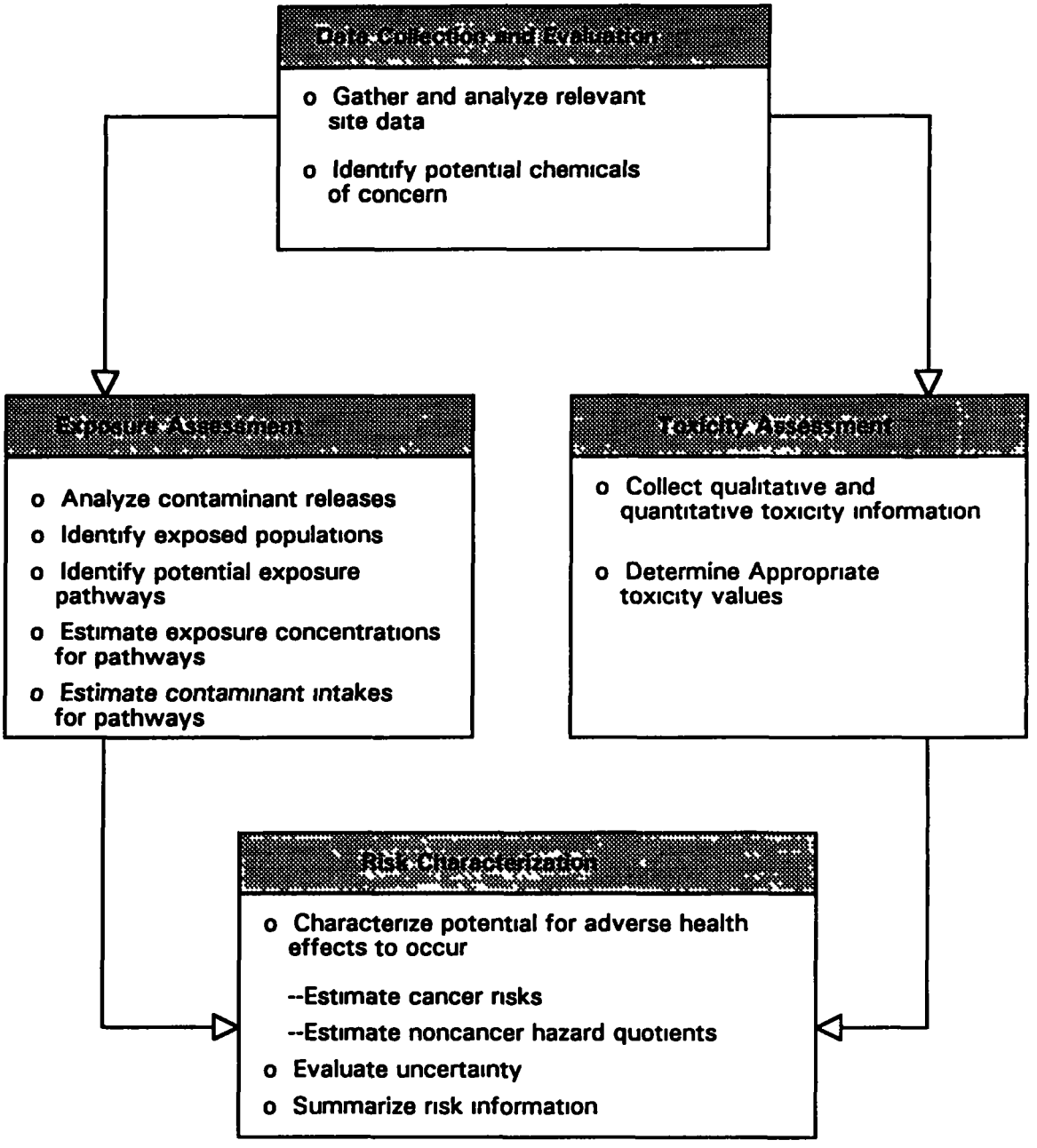
1.3.1 Data Collection and Evaluation

Data collection and evaluation involves gathering and analyzing the site data relevant to the human health evaluation and identifying the substances present at the site that are the focus of the risk evaluation process. The information specific to DNAPL characteristics and occurrence is summarized in the DNAPL Study Field Data Report (AHA, 1993b). The site hydrogeologic characteristics are described in this report as well as in earlier documents (REI, 1986; AHA, 1986 and 1989).

[4] Baseline risks are risks that might exist if no remediation or institutional controls were applied at the site

FIGURE 1-1

RISK EVALUATION PROCESS



1.3.2 Exposure Assessment

The exposure assessment is conducted to estimate the magnitude of actual and/or potential human exposures, the frequency and duration of these exposures, and the pathways by which humans are potentially exposed. The results of the exposure assessment are pathway-specific intakes for reasonable maximum estimates of current and future exposures to individual substances.

Current exposure estimates are used to determine whether a threat exists based on existing exposure conditions. For the French Limited site, this analysis includes consideration of the existing groundwater and subsoil remedial system operation. This system consists of a subsurface sheetpile containment wall surrounding the former disposal lagoon, and a network of pumping and injection wells. The wells are operated to control contaminated groundwater migration, and remove contaminants from the subsurface by a combination of groundwater flushing and the promotion of in-situ bioremediation.

Future exposure estimates are used to provide an understanding of potential future exposures and threats including a qualitative estimate of the likelihood of such exposures occurring. For this Risk Evaluation the future exposure scenarios consider the situation that will exist when the current groundwater and subsoil remedial system is no longer operational and the lagoon has been backfilled and closed. The existing subsurface portion of the sheetpile containment wall surrounding the former disposal lagoon is assumed to remain in place. This future condition assumes that the DNAPL impacted areas will still exist and that no additional measures for containment or control of these areas are in place. In conformance with EPA guidelines for Baseline Risk Evaluations (EPA, 1989c), future exposure scenarios also assume that no institutional controls or deed restrictions will be imposed on areas adjacent to the site, even though such controls are being considered.

Conducting an exposure assessment involves:

- analyzing contaminant releases;
- identifying exposed populations;
- identifying significant potential pathways of exposure;
- estimating exposure point concentrations for identified pathways, based on environmental monitoring data and predictive chemical modeling results;
- estimating contaminant intakes for identified pathways.

1.3.3 Toxicity Assessment

The purpose of the toxicity assessment is to weigh available evidence regarding the potential for particular chemicals to cause adverse effects in exposed individuals or the environment and, to provide, where possible, an estimate of the relationship between the extent of exposure to a chemical and the increased likelihood and/or severity of adverse effects. EPA has performed the toxicity assessment step for numerous chemicals and has made available the resulting toxicity information and toxicity values, which have undergone extensive peer review. The latest information on Toxicity Assessments of specific chemicals is accessible through a computerized database known as the Integrated Risk Information System (IRIS) (EPA, 1988a). The risk evaluation for the DNAPL-impacted areas of French Limited site relied exclusively on existing toxicity information, developed on specific chemicals, that is accepted by the EPA.

The toxicity assessment component of the risk evaluation considers:

- the types of adverse health effects associated with chemical exposures;
- the relationship between magnitude of exposure and adverse effects,
- related uncertainties such as the weight of evidence of a particular chemicals' carcinogenicity in humans

1.3.4 Risk Characterization

The risk characterization summarizes and combines outputs of the exposure and toxicity assessment to characterize risk, both in quantitative expressions and qualitative statements. During risk characterization, chemical-specific toxicity information is compared against both measured contaminant exposure levels and those levels predicted through fate and transport modeling to determine whether current or future levels at or near the site are of potential concern.

2.0 SITE CHARACTERIZATION

This section of the report describes the characteristics of the French Limited site particularly with respect to potential exposure of nearby populations to chemicals associated with DNAPL-impacted areas of the site. This information is then used as the setting for the exposure assessment discussed in Chapter 3 of this report. Basic site characteristics such as climate, vegetation, groundwater and surface water hydrology, are identified. Populations are also identified and are described with respect to characteristics that influence exposure, such as location relative to the site, activity patterns, and presence of sensitive subpopulations Characteristics of any potential future populations that may differ under an alternate land use, are also described.

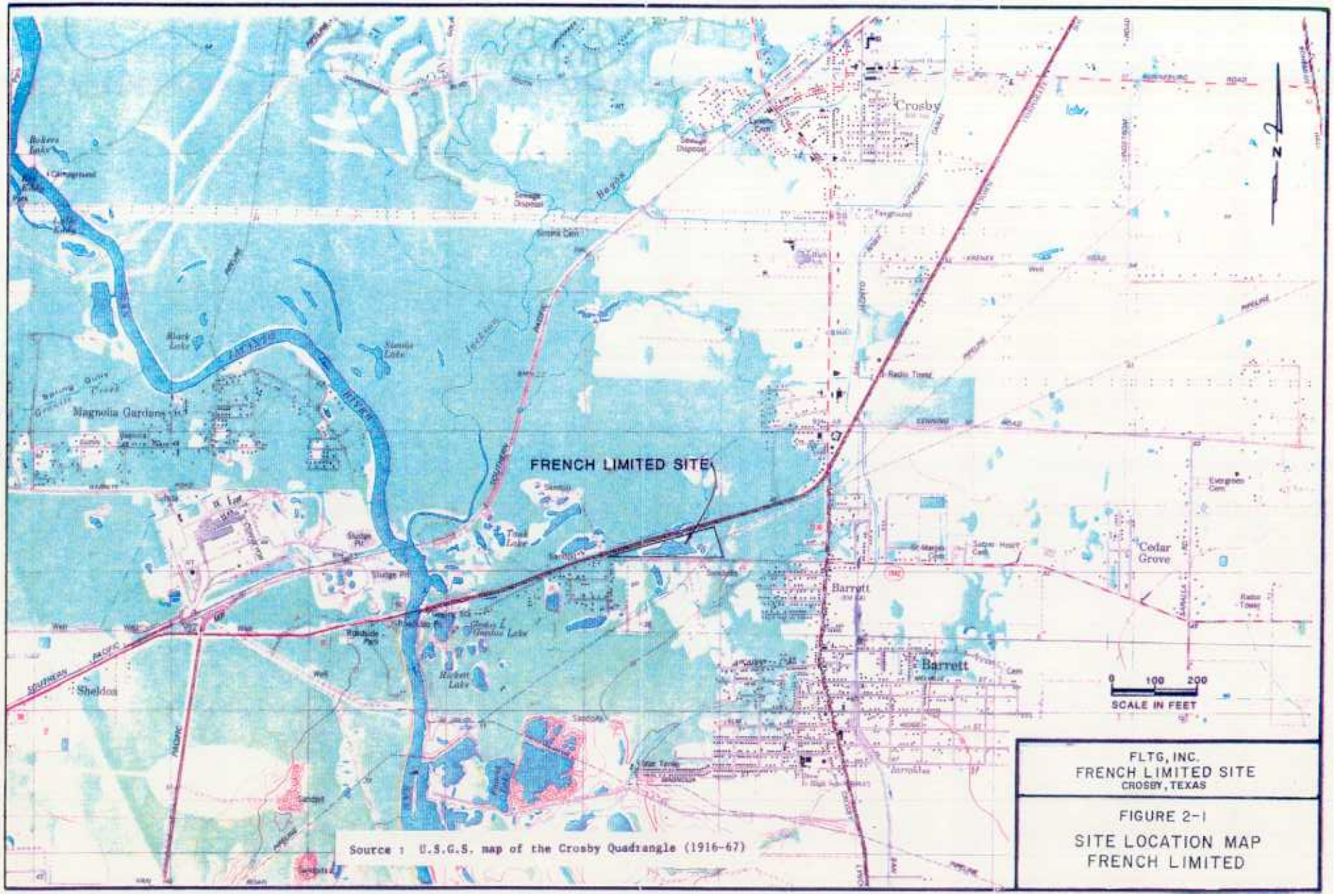
2.1 Location and Topographic Setting

The French Limited site is a former sand pit (now referred to as the French Limited Lagoon) located within the alluvial plain of the San Jacinto River near Crosby, Texas, approximately 20 miles northeast of Houston (Figure 2-1). Currently, the highest ground surface elevations at the site are less than 18 feet above mean sea level. Based upon the 1963 U.S. Geological Survey (U.S.G.S.) elevation survey, the U.S. Army Corps of Engineers defined the 100-year floodplain in the vicinity of the site as land elevation below 28 feet above mean sea level. Local elevation change between 1963 and 1993 due to land subsidence is estimated to be less than 2 feet. The net subsidence measured at benchmark D690, approximately 4000 feet west of the site, was 1.23 feet between 1963 and 1983 (REI, 1986).

2.2 Vegetation

The land in the immediate vicinity of the site in the San Jacinto River floodplain is largely undeveloped and is vegetated with shrubs and mature trees. There are several abandoned sand pits in the vicinity of the site that now exist as fresh water ponds. The area surrounding the site, to the west, north, east, and southeast, has predominantly forest canopy and swamp vegetation. Trees include loblolly pine, slash pine, water oak, willow oak, elm, green ash, cottonwood, sweetgum, and, in the wetter areas, bald cypress. Sesban, a leguminous shrub, is common to wet disturbed areas of the site.

Immediately to the east of the Riverdale subdivision is the Old Harris County Landfill. Much of the landfill is covered by grasses and shrubs Some swampy areas surrounding the site and portions of the landfill have been backfilled with roadbed material to provide access to groundwater remediation wells associated with the site. These high traffic areas remain largely unvegetated.



Source : U.S.G.S. map of the Crosby Quadrangle (1916-67)

FLTG, INC.
FRENCH LIMITED SITE
CROSBY, TEXAS

FIGURE 2-1
SITE LOCATION MAP
FRENCH LIMITED

2.3 Soil Types

Soils in the Houston area and much of the Southeast Texas Coastal Plain are dominated by vertisols. These soils are derived from clay-textured parent material and, characteristically, swell when wet and shrink and crack when dry. Organic carbon content (1.0% to 1.5%) and pH (5 to 7), tend to be relatively uniform over the soil profile due to natural mixing that occurs as a result of repeated swelling and shrinking.

In the vicinity of the French Limited site, soils within the San Jacinto floodplain are less uniform due to the variability of the texture of the parent material and period of soil development. The less developed of these soils, which were derived from sandy parent material, are classified as entisols and do not have the shrink-swell characteristics of vertisols. Organic carbon content of these soils is usually highest at the surface (1.0% to 1.5%) and decreases with depth (0 to 1.5%). The pH is typically neutral to slightly acidic (5 to 7) from within a few inches from the surface to the depth of the profile, and slightly acidic to acidic (3 to 5) close to the surface.

2.4 Geologic Setting

2.4.1 Regional Geology

The French Limited site is in the Gulf of Mexico Coastal Plain Physiographic Province. The land is gently rolling to flat, and is underlain by a gulfward-thickening wedge of unconsolidated to semiconsolidated, sedimentary rocks of Cenozoic age. Sediments consist primarily of sand, silt and clay derived by erosion from nearby upland areas. These sediments dip slightly toward the Gulf and are in excess of 30,000 feet thick in the Southeast Texas portion of the Gulf Coast Plain.

The Houston area is located in a Seismic Zone 0 according to the Uniform Building Code. The primary geologic hazards in the area are subsidence caused by deep groundwater withdrawal and related ground faulting. Maximum subsidence in the Houston area has exceeded 8 feet over the last 75 years or so. Ground faults in the Houston area are generally inclined 60 to 70 degrees from the horizontal, extend for thousands of feet, and are roughly parallel to the coast. Based upon a review of available data sources, no known faults pass through the site area.

2.4.2 Local Geology

Shallow alluvial deposits, consisting of sands, silts and clays, extend to a depth of about 55 feet in the vicinity of the site. These shallow alluvial sediments were deposited by the San Jacinto River within an incised channel in the Late Pleistocene Lower Beaumont Formation. The Upper Alluvial Zone is subdivided into four

hydrogeologic units, designated UNC, S1, C1 and INT, that may be correlated across the site (AHA, 1989). In the vicinity of the site, the Beaumont Formation consists primarily of clay with discontinuous silt and sand lenses and functions as an aquitard between the shallow alluvial zone and the underlying regional Chicot Aquifer (AHA, 1986). The descriptions of the alluvial units and the underlying Pleistocene and older formations are summarized in Table 2-1.

2.5 Hydrogeologic Setting

Lateral groundwater flow in the Upper Alluvial Zone occurs primarily in the relatively more permeable S1 and INT units (Table 2-1). The S1 is a relatively well-sorted, medium to coarse grained, unconsolidated sand with little clay. It has an average thickness of about 20 feet and a permeability ranging from 10^{-3} to 10^{-2} cm/sec. Well yields in the S1 unit range from 2 to 15 gallons per minute (gpm). The INT is an interbedded silt and fine sand unit with thin clay zones. It has an average thickness of about 20 feet and an average permeability ranging from 10^{-4} to 10^{-3} cm/sec. Well yields in the INT unit range from 0.25 to 3 gpm.

Natural groundwater flow direction in the vicinity of the site is generally to the south, but is influenced locally by interaction with ponds and sloughs. Ponds tend to act as groundwater recharge sources following heavy rainfall events, and as groundwater discharge areas at other times. Prior to remedial activities, the French Limited lagoon acted as a recharge source because dikes built around the lagoon allowed the water level to rise a few feet above the surrounding land surface.

Groundwater within the UNC and S1 units exists predominantly under water table conditions (unconfined). Saturated groundwater conditions are typically encountered within 2 to 3 feet of natural ground surface, within the UNC unit. The unsaturated zone in the vicinity of the site is very thin and occurs entirely within the relatively low-permeability UNC unit. Potential vapor-phase contaminant migration in the unsaturated zone is therefore considered to be insignificant.

There is a slight natural downward component of groundwater flow in the site area. The laterally discontinuous C1 unit acts as an aquitard between the S1 and INT units, creating primarily confined conditions in the INT unit. Hydraulic communication between the S1 and INT units, and resulting contaminant migration patterns, is strongly influenced by the thickness of the intervening C1 clay which varies from 0 to about 8 feet across the site.

Previous Remedial Investigations (LAN, 1985: REI, 1986) and Hydrogeologic Characterization studies (AHA, 1986 and 1989) conducted at the French Limited site concluded that the groundwater flow system of the shallow alluvial sediments is essentially hydraulically separated from the Chicot Aquifer by the low permeability Beaumont Formation.

TABLE 2-1

Description of Geologic Units at the French Limited Site

Shallow Alluvial Zone

Unit	Approximate Depth (ft)	Description
UNC	0 to 10	Silty and clayey, medium to fine sand mixed with variable amounts of natural organic matter. Unit represents overbank flood deposits and reworked S1 sand
S1	10 to 30	Clean medium to coarse sand with minor amounts of fine gravel. Unit represents primary fluvial channel deposits.
C1	30 to 35	Laterally discontinuous clay with minor thin silt and fine sand layers Where present, it functions as an aquitard between the S1 and INT units Unit represents overbank flood deposits and/or oxbow lake deposits
INT	35 to 55	Interbedded fine sand and clayey silt Unit represents overbank flood deposits

Pleistocene and older Formations.

Unit	Approximate Depth (ft)	Description
Beaumont Formation (C2)	55 to 200	Dominantly clay deposit with minor thin silt and fine sand layers. In the site area a 10 foot sand layer, the S2 Unit, occurs at a depth of 125 feet. Unit represents a fluvial-deltaic environment.
Chicot and Evangeline aquifers	200 to 2400	A sequence of fluvial-deltaic sands, silts and clays. The primary water supply for Houston.

2.6 Nature and Extent of Subsurface Contamination

The French Limited lagoon was excavated to approximately the base of the S1 unit. Liquid chemical wastes, that were deposited primarily at the eastern and western extremities of the lagoon, form the primary source of subsurface contamination at the site. Disposal of chemicals resulted in the formation of a chemical-rich sludge on the bottom of the lagoon. Major contaminants in the lagoon sludges include polychlorinated biphenols (PCBs), chlorinated and non-chlorinated solvents and volatile organics, and polynuclear hydrocarbons (PAHs). Dense, non-aqueous phase liquids (DNAPLs), containing a significant component of chlorinated solvents, also migrated into the underlying subsoils. Subsequent solubilization of organic liquids and leaching of lagoon sludges and contaminated subsoils resulted in dissolved phase groundwater contamination (AHA, 1993b). The major contaminants and maximum concentrations found in the various media at the French Limited site, outside the sheetpile containment wall surrounding the former disposal lagoon, are summarized in Table 2-2. Additional DNAPL samples were obtained and submitted for analyses after the release of the DNAPL Study Field Data Report (AHA, 1993b). These analytical results are included as Appendix C of this report. Table 2-2 reflects the most recent DNAPL analytical results.

The nature and extent of identified DNAPL-impacted areas at the French Limited site were defined in the DNAPL Study Field Data Report (AHA, 1993b). The three identified DNAPL areas, termed the S1-16, S1-13 and INT-11 Areas, are shown in Figure 2-2. Groundwater monitoring data, collected over the course of remedial system operation, suggest a fourth potential DNAPL source area, termed the INT-West Area, located on the western extremity of the lagoon (Figure 2-2). These four potential source areas for continued groundwater contamination are the focus of this Risk Evaluation. The maximum constituent concentrations detected in groundwater in these four areas are summarized in Table 2-3. Migration and distribution of contaminated groundwater is primarily influenced by source area conditions, groundwater flow paths and aquifer characteristics.

The Field Data Report (AHA, 1993b), documents that DNAPL migration is influenced by the existence, thickness and configuration of the C1 clay underlying the lagoon. In areas where a sufficient thickness (>2 feet) of low permeability C1 clay occurs below the base of the lagoon, vertical DNAPL migration is restricted and accumulation on top of the C1 clay tends to occur. This has been confirmed in the S1-16 and S1-13 areas of the site (Figure 2-2). Areas of DNAPL occurrence and/or associated high dissolved contaminant concentrations in the INT unit tend to occur downgradient from areas of thin (<2 feet) C1 clay or where the original sand pit excavation penetrated through the C1 unit. This has been confirmed in the INT-11 and INT-West areas of the site (Figure 2-2).

TABLE 2-2

Maximum Concentration of Chemical Constituents Detected in Subsurface Media

Chemical Compound	Synonym	CAS #	DNAPL Maximum Concentration (mg/kg)	SOIL Maximum Concentration (mg/kg)	Groundwater Maximum Concentration (ug/L)	French Ltd. Cleanup Criteria (1) (ug/L)
VOLATILES						
chloromethane	methyl chloride	74-87-3	ND	ND	12	----
vinyl chloride	chloroethene	75-01-4	ND	22	16,000	2
chloroethane	ethyl chloride	75-00-3	2,300	110	15,000	10
methylene chloride	dichloromethane	75-09-2	1,600	61	43,581	5
acetone	methyl ketone	67-64-1	ND	9.2	110,000	3,500
1,1-dichloroethene (1,1-DCE)		75-35-4	2,300	330	1,800	7
1,1-dichloroethane (1,1-DCA)		75-34-3	5,000	190	33,000	3500
total 1,2-dichloroethene (2)		540-59-0	80,000	3,300	250,000	100
chloroform	trichloromethane	67-66-3	220,000	22,000	850,000	100
1,2-dichloroethane (1,2-DCA)		107-06-2	140,000	16,000	860,000	5
2-butanone	methyl ethyl ketone	78-93-3	23	ND	4,400	1,700
carbon tetrachloride		56-23-5	190,000	16,000	110,000	5
vinyl acetate		108-05-4	150	ND	1,500	35,000
trichloroethene		79-01-6	26,000	6,200	18,957	5
1,1,2-trichloroethane (1,1,2-TCA)		79-00-5	ND	ND	556	5
benzene		71-43-2	530	42	3,800	5
4-methyl-2-pentanone	methyl isobutyl ketone	108-10-1	27	ND	2,100	1,700
tetrachloroethene	perchloroethene (PCE)	127-18-4	57,000	6,300	20,146	5
1,1,2,2-tetrachloroethane		79-34-5	19	45	674	2
toluene		108-88-3	780	70	1,200	1,000
ethylbenzene		100-41-4	710	67	690	700
xylene		1330-20-7	8,600	170	1,533	10,000

ND = Not Detected NA = Not Analyzed

(1) = Reference French Limited Site Remediation Quality Assurance Project Plan, December, 1993 Criteria given for total 1,2-DCE is actually for trans-1,2-DCE.
(2) = Prior to 12/92, groundwater was analyzed for trans-1,2-dichloroethene In this table, total 1,2-DCE (i e , sum of cis and trans isomers) is assumed equal to trans-1,2-DCE

TABLE 2-2 (Cont.)

Maximum Concentration of Chemical Constituents Detected in Subsurface Media

Chemical Compound	Synonym	CAS #	DNAPL Maximum Concentration (mg/kg)	SOIL Maximum Concentration (mg/kg)	Groundwater Maximum Concentration (ug/L)	French Ltd. Cleanup Criteria (1) (ug/L)
SEMI-VOLATILES						
phenol		108-95-2	ND	0.20	1,200	21,000
2-methylphenol	2-cresol	95-48-7	ND	ND	8	—
4-methylphenol	4-cresol	106-44-5	ND	ND	17	—
hexachloroethane		67-72-1	33,000	4,900	140	—
2,4-dimethylphenol		105-67-9	ND	180	ND	—
1,2,4-trichlorobenzene		120-82-1	940	260	7	—
naphthalene		91-20-3	5,100	870	200	140
hexachlorobutadiene		87-68-3	230,000	41,000	ND	—
2-methylnaphthalene		91-57-6	1,600	320	14	10
acenaphthylene		208-96-8	170	18	ND	140
acenaphthene		83-32-9	2,000	250	18	2,100
dibenzofuran		132-64-9	1,200	250	9	350
fluorene		86-73-7	1,900	160	13	—
hexachlorobenzene		118-74-1	3,700	310	ND	—
phenanthrene		85-01-8	3,300	360	11	—
anthracene		120-12-7	250	80	ND	—
fluoranthene		206-44-0	880	200	1	—
pyrene		129-00-0	910	280	ND	—
benzo(A)anthracene		56-55-3	170	46	ND	—
bis(2-ethylhexyl)phthalate		117-81-7	ND	45	46	2.5
chrysene		218-01-9	160	71	ND	—
benzo(B)fluoranthene		205-99-2	76	20	ND	—
benzo(A)pyrene		50-32-8	ND	6	ND	—
indeno(1,2,3-CD)pyrene		193-39-5	ND	0 44	ND	—
dibenzo(A,H)anthracene		53-70-3	ND	0 25	ND	—
benzo(GHI)perylene		191-24-2	ND	3	ND	—

ND = Not Detected NA = Not Analyzed

(1) = Reference French Limited Site Remediation Quality Assurance Project Plan, December, 1993

TABLE 2-2 (Cont.)

Maximum Concentration of Chemical Constituents Detected in Subsurface Media

Chemical Compound	Synonym	CAS #	DNAPL Maximum Concentration (mg/kg)	SOIL Maximum Concentration (mg/kg)	Groundwater Maximum Concentration (ug/L)	French Ltd. Cleanup Criteria (1) (ug/L)
PESTICIDES						
alpha-BHC	alpha-hexachlorocyclohexane	319-84-6	NA	NA	20	----
beta BHC	beta-hexachlorocyclohexane	319-85-7	NA	NA	7	----
delta BHC	delta-hexachlorocyclohexane	319-86-8	NA	NA	17	----
gamma-BHC Lindane	gamma-hexachlorocyclohexane	58-89-9	NA	NA	17	----
aldrin		309-00-2	NA	NA	03	----
4,4 DDE	DDE	72-55-9	NA	NA	3	----
endrin		72-20-8	NA	NA	5	----
endrin aldehyde		7421-93-4	NA	NA	29	----
heptachlor		76-44-8	NA	NA	0 1	----
PCBs						
PCB-1016	AROCLOR-1016	12674-11-2	ND	NA	ND	----
PCB-1221	AROCLOR-1221	11104-28-2	ND	NA	ND	----
PCB-1232	AROCLOR-1232	11141-16-5	ND	NA	ND	----
PCB-1242	AROCLOR-1242	53469-21-9	ND	NA	ND	----
PCB-1248	AROCLOR-1248	12672-29-6	ND	NA	ND	----
PCB-1254	AROCLOR-1254	11097-69-1	ND	NA	ND	----
PCB-1260	AROCLOR-1260	11096-82-5	ND	NA	ND	----
METALS						
arsenic		7440-38-2	NA	NA	103	50
chromium		7440-47-3	NA	NA	434	100
copper		7440-50-8	NA	NA	40	1,300
zinc		7440-66-6	NA	NA	114	10,000

ND = Not Detected NA = Not Analyzed

(1) = Reference French Limited Site Remediation Quality Assurance Project Plan, December, 1993

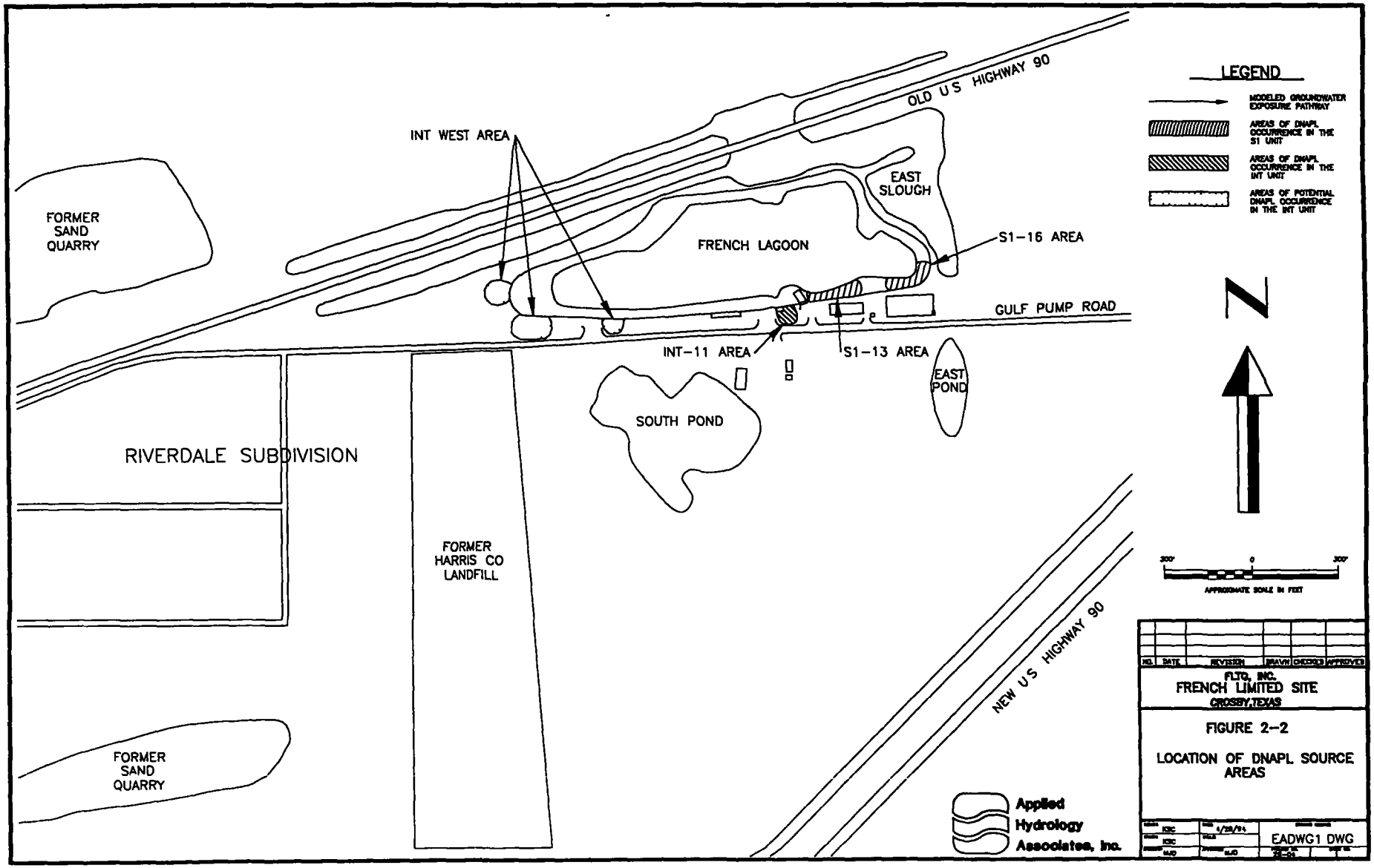

OLD U S HIGHWAY 90
INT WEST AREA
EAST SLOUGH
FORMER SAND QUARRY
FRENCH LAGOON
S1-16 AREA
GULF PUMP ROAD
INT-11 AREA
S1-13 AREA
EAST POND
SOUTH POND
RIVERDALE SUBDIVISION
FORMER HARRIS CO LANDFILL
FORMER SAND QUARRY
NEW U S HIGHWAY 90
LEGEND
MODELED GROUNDWATER EXPOSURE PATHWAY
AREAS OF DNAPL OCCURRENCE IN THE S1 UNIT
AREAS OF DNAPL OCCURRENCE IN THE INT UNIT
AREAS OF POTENTIAL DNAPL OCCURRENCE IN THE INT UNIT
N
300' 0 300'
APPROXIMATE SCALE IN FEET
NO. DATE REVISION DRAWN CHECKED APPROVED
FLTG, INC.
FRENCH LIMITED SITE
CROSBY, TEXAS
FIGURE 2-2
LOCATION OF DNAPL SOURCE AREAS
Applied Hydrology Associates, Inc.
EADWG1 DWG

TABLE 2-3

Maximum Groundwater Concentration of Chemical Constituents Detected in INT-West, INT-11, S1-16, and S1-13 Areas (5)

Chemical Compound	INT-WEST Groundwater Maximum Concentration (ug/L) (1)	INT-11 Groundwater Maximum Concentration (ug/L) (2)	S1-16 Groundwater Maximum Concentration (ug/L) (3)	S1-13 Groundwater Maximum Concentration (ug/L) (4)	French Ltd. Cleanup Criteria (6) (ug/L)
VOLATILES					
chloromethane	ND	12	ND	ND	----
vinyl chloride	16,000	6,000	1,400	7,278	2
chloroethane	270	15,000	86	2,558	10
methylene chloride	640	30,000	1,100	43,581	5
acetone	110,000	81,000	33,443	76,036	3,500
1,1-dichloroethene (1,1-DCE)	160	1,800	52	1,137	7
1,1-dichloroethane (1,1-DCA)	3,300	33,000	974	5,658	3,500
total 1,2-dichloroethene (7)	6,200	250,000	2,000	63,613	100
chloroform	250	850,000	3,700	131,131	100
1,2-dichlorethane (1,2-DCA)	8,700	860,000	6,600	20,000	5
2-butanone	4,400	580	1,700	ND	1,700
carbon tetrachloride	66	110,000	10	2	5
vinyl acetate	1,500	180	ND	ND	35,000
trichloroethene	680	6,500	12	18,957	5
1,1,2-trichloroethane (1,1,2-TCA)	550	5	ND	556	5
benzene	3,600	1,200	3,800	1,300	5
4-methyl-2-pentanone	2,100	ND	ND	ND	1,700
tetrachloroethene	77	20,146	ND	9,474	5
1,1,2,2-tetrachloroethane	ND	138	ND	674	2
toluene	1,200	202	730	364	1,000
ethylbenzene	690	247	430	119	700
xylene	1,533	535	290	269	10,000

ND = Not Detected NA = Not Analyzed

(1) INT-West Area includes Well Nos REI-10-3, REI-10-2, INT 72, INT-73, INT-74, INT-75, INT-97, INT-101, INT-112, and INT-113

(2) INT-11 Area includes Well Nos INT-11, INT-71, INT-114, INT-120, INT-121, INT-122, INT-123, INT-124, INT-125, INT-126, INT-127, INT-128, INT-202, and INT-203

(3) S1-16 Area includes Well Nos S1-105, S1-127, S1-128, S1-129, S1-130, S1-131, S1-132, S1-133, and S1-134

(4) S1-13 Area includes Well Nos S1-104, S1-120, S1-121, S1-122, and S1-123

(5) Maximum groundwater concentrations reported for areas outside the lagoon floodwall only

(6) Reference French Limited Site Remediation Quality Assurance Project Plan, December, 1993 Criteria given for total 1,2-DCE is actually for trans-1,2-DCE

(7) Prior to 12/92, groundwater was analyzed for trans-1,2-dichloroethene In this table, total 1,2-DCE (i e , sum of cis and trans isomers) is assumed equal to trans-1,2-DCE

TABLE 2-3 (Cont.)

Maximum Groundwater Concentration of Chemical Constituents Detected in INT-West, INT-11, S1-16, and S1-13 Areas (5)

Chemical Compound	INT-WEST Groundwater Maximum Concentration (ug/L) (1)	INT-11 Groundwater Maximum Concentration (ug/L) (2)	S1-16 Groundwater Maximum Concentration (ug/L) (3)	S1-13 Groundwater Maximum Conc. (ug/L) (4)	French Ltd Cleanup Criteria (6) (ug/L)
SEMI-VOLATILES					
phenol	1,200	30	390	2	21,000
2-methylphenol	ND	8	ND	ND	—
4-methylphenol	ND	17	ND	ND	—
hexachloroethane	ND	140	ND	ND	—
2,4-dimethylphenol	ND	ND	ND	ND	—
1,2,4-trichlorobenzene	ND	7	ND	ND	—
naphthalene	200	110	13	15	140
hexachlorobutadiene	ND	ND	ND	ND	—
2-methylnaphthalene	3	14	ND	ND	10
acenaphthylene	ND	ND	ND	ND	140
acenaphthene	ND	18	ND	2	2,100
dibenzofuran	ND	9	ND	ND	350
fluorene	ND	13	ND	ND	—
hexachlorobenzene	ND	ND	ND	ND	—
phenanthrene	ND	11	ND	ND	—
anthracene	ND	ND	ND	ND	—
fluoranthene	ND	1	ND	ND	—
pyrene	ND	ND	ND	ND	—
benzo(A)anthracene	ND	ND	ND	ND	—
bis(2-ethylhexyl)phthalate	12	46	25	7	2 5
chrysene	ND	ND	ND	ND	—
benzo(B)fluoranthene	ND	ND	ND	ND	—
benzo(A)pyrene	ND	ND	ND	ND	—
indeno(1,2,3-CD)pyrene	ND	ND	ND	ND	—
dibenzo(A,H)anthracene	ND	ND	ND	ND	—
benzo(GHI)perylene	ND	ND	ND	ND	—

ND = Not Detected NA = Not Analyzed

(1) INT-West Area includes Well Nos REI-10-3, REI-10-2, INT-72, INT-73, INT-74, INT-75, INT-97, INT-101, INT-112, and INT-113

(2) INT-11 Area includes Well Nos INT-11, INT-71, INT-114, INT-120, INT-121, INT-122, INT-123, INT-124, INT-125, INT-126, INT-127, INT-128, INT-202, and INT-203

(3) S1-16 Area includes Well Nos S1-105, S1-127, S1-128, S1-129, S1-130, S1-131, S1-132, S1-133, and S1-134

(4) S1-13 Area includes Well Nos S1-104, S1-120, S1-121, S1-122, and S1-123

(5) Maximum groundwater concentrations reported for areas outside the lagoon floodwall only

(6) Reference French Limited Site Remediation Quality Assurance Project Plan, December, 1993

TABLE 2-3 (Cont.)

Maximum Groundwater Concentration of Chemical Constituents Detected in INT-West, INT-11, S1-16, and S1-13 Areas (5)

Chemical Compound	INT-WEST Groundwater Maximum Concentration (ug/L) (1)	INT-11 Groundwater Maximum Concentration (ug/L) (2)	S1-16 Groundwater Maximum Concentration (ug/L) (3)	S1-13 Groundwater Maximum Conc. (ug/L) (4)	French Ltd. Cleanup Criteria (6) (ug/L)
PESTICIDES					
alpha-BHC	0 03	20	ND	5	—
beta BHC	ND	ND	ND	7	—
delta BHC	ND	17	ND	4	—
gamma-BHC	ND	17	ND	8	—
aldrin	0 03	ND	ND	ND	—
4,4-DDE	ND	3	ND	ND	—
endrin	ND	5	ND	ND	—
endrin aldehyde	ND	29	ND	ND	—
heptachlor	ND	ND	ND	0 1	—
PCBs					
PCB-1016	ND	ND	ND	ND	—
PCB-1221	ND	ND	ND	ND	—
PCB-1232	ND	ND	ND	ND	—
PCB-1242	ND	ND	ND	ND	—
PCB-1248	ND	ND	ND	ND	—
PCB-1254	ND	ND	ND	ND	—
PCB-1260	ND	ND	ND	ND	—
METALS					
arsenic	103	ND	10	40 3	50
chromium	ND	ND	43 4	ND	100
copper	ND	ND	40	ND	1,300
zinc	27 6	22	114	21 9	10,000

ND = Not Detected NA = Not Analyzed

(1) INT-West Area includes Well Nos REI-10-3, REI-10-2, INT-72, INT-73, INT-74, INT-75, INT-97, INT-101, INT-112, and INT-113

(2) INT-11 Area includes Well Nos INT-11, INT-71, INT-114, INT-120, INT-121, INT-122, INT-123, INT-124, INT-125, INT-126, INT-127, INT-128, INT-202, and INT-203

(3) S1-16 Area includes Well Nos S1-105, S1-127, S1-128, S1-129, S1-130, S1-131, S1-132, S1-133, and S1-134

(4) S1-13 Area includes Well Nos S1-104, S1-120, S1-121, S1-122, and S1-123

(5) Maximum groundwater concentrations reported for areas outside the lagoon floodwall only

(6) Reference French Limited Site Remediation Quality Assurance Project Plan, December, 1993

Detailed field investigations (AHA, 1993b) confirm that the C2 clay unit, due to its fine-grained nature and low permeability, restricts the downward migration of DNAPLs and groundwater containing dissolved contaminants. Consequently, contamination associated with the French Limited site is restricted to the Upper Alluvial Zone.

The ability of the C2 Clay to restrict vertical DNAPL movement is supported by the observation of DNAPL on top of the C2 clay in the INT-11 area of the site, but no indication of DNAPL penetration of the C2 clay (AHA, 1993b). Monitoring of the S2 sand confirms that no detectable groundwater contamination occurs in this first transmissive unit underlying the Upper Alluvial Zone. The low permeability of the C2 is also indicated by a dramatic drop in potentiometric head through this zone and by its hydraulic response to a long term pumping test in the S2 unit (AHA, 1986).

The S1 and INT units are the major transmissive units within the Upper Alluvial Zone and are the focus of groundwater and subsoil remediation efforts at the site. The hydrogeologic and contaminant transport characteristics of the two units are different. Accordingly, the French Limited groundwater and subsoil remedial system includes separate networks of production and injection wells in the two units, so that they can be remediated separately.

The S1 Unit has relatively little clay and organic matter and, consequently, does not have a high adsorption capacity for organic constituents. Dissolved organics in the S1 Unit migrate with relatively little retardation due to limited partitioning onto the aquifer matrix. Contaminated groundwater in the S1 Unit had migrated approximately 500 feet to the south of the lagoon prior to the start of remedial activities in January 1992. Remediation efforts have been successful in significantly reducing dissolved groundwater concentrations in the S1 Unit. Groundwater monitoring data indicated that by November, 1993, groundwater clean-up criteria in the S1 unit, for compounds other than benzene, had been met in all areas south of Gulf Pump Road and most of the area between Gulf Pump Road and the floodwall.

The fine-grained and relatively low permeability of the INT Unit results in a relatively slow rate of groundwater and dissolved contamination migration. The high percentage of clay and more abundant organic matter results in a strong potential for partitioning of organics from the dissolved phase to the adsorbed phase. In addition, because of the finely interbedded nature of the unit, diffusion from zones of higher permeability to finer-grained interbeds is likely to occur. Both processes have the effect of retarding the migration of dissolved contaminants in groundwater. The same processes also complicate the remediation of the INT Unit because slow desorption and diffusion of contaminants from the soil back into the groundwater will reduce the ability to remove contaminants by flushing. As a result of the INT characteristics, remedial progress in the INT unit has been slower than that in the S1 unit.

In-situ bioremediation was included in the remedial system in order to enhance the contaminant removal efficiency in both the S1 and INT units, by stimulating degradation of absorbed-phase organics.

2.7 Surface Water Hydrology

The surface water hydrology of the site is dominated by the presence of a shallow water table, abundant rainfall, surface topography of the San Jacinto River floodplain, and the periodic flooding of the river. The entire site falls within the 100-year floodplain of the San Jacinto River. Many of the shallow surface water bodies that surround the site arose from the inflow of groundwater and surface water into abandoned sand quarries. The distribution of these shallow surface water bodies in the vicinity of the site is illustrated in Figure 2-1. In addition, intermittent surface water bodies occur in the low-lying ditches and surface depressions during heavy precipitation or flooding events.

Annual rainfall at the site averages approximately 52 inches with the greatest seasonal rainfall occurring during the late spring to early summer and early fall. Annual evaporation averages approximately 50 inches and is typically greatest during the summer and least during December, January, and February (LAN, 1985)

Surface water flow between the ponds, sloughs, and swamps is limited to the periodic flooding of the San Jacinto River and runoff during heavy precipitation events. During these events, overland flow occurs, generally, in a clockwise direction around the site from the northwest to the southwest. This local flow pattern is controlled by the topography of the San Jacinto River floodplain and generally follows the path of the old river meander (LAN, 1985).

2.8 Potentially Exposed Populations

2.8.1 Location of Current Populations Relative to the Site

The French Limited site is approximately one mile south of Crosby, Texas and one-half mile west of Barrett, Texas (Figure 2-1). The combined population of the Crosby/Barrett area is approximately 6,000 based on the 1990 census.

Currently, there are no residents living on the French Limited site. The population with the greatest potential for exposure to contaminants are people working at the site. The closest residential properties are in the Riverdale Subdivision, approximately 500 feet southwest of the French Lagoon. These properties consist of single-family homes on one-acre lots. Many of the Riverdale Subdivision properties have shallow domestic wells completed in the Upper Alluvial sediments.

Municipal water supply wells for the towns of Crosby and Barrett do exist within a 1-mile radius of the site, but these wells are completed in the Chicot Aquifer, typically at depths in excess of 200 feet. The Chicot Aquifer is hydrogeologically separated from the shallow alluvial aquifer of the French Limited site. As a result, public water supply consumers of Crosby and Barrett are not considered to be a potentially exposed population through this drinking water pathway.

The water supply well used to support activities at the French Limited site is located approximately 500 feet east of the site water treatment plant. The well is also completed in the Chicot Aquifer at a depth of 220 feet. Routine monitoring of this well has confirmed that no organic constituents related to the French Limited site exist in the Chicot aquifer unit.

2.8.2 Current Land Use

Land use in the Crosby/Barrett area is primarily residential with the closest residential properties in the Riverdale Subdivision. Land use in the undeveloped, immediate vicinity of the French Limited site is dominantly recreational The abandoned sand pits in the area are currently frequented by sport fisherman and the San Jacinto River is used for boating, fishing, and water sports. Commercial businesses are concentrated along highway FM-2100. A car dealership operates on Gulf Pump Road approximately one half mile east of the site. Farming occurs in the outlying areas and some sand mining operations continue to operate along the San Jacinto River and its tributaries.

The closest industrial operation to the site is the Champion pulp and paper mill approximately 2 miles west of the site on the west side of the San Jacinto River Remedial activities are currently active at the French Limited superfund site and at the Sikes superfund site northwest of the old Highway 90 on the east side of the San Jacinto River.

2.8.3 Future Land Use

The site property is likely to be excluded from future development by institutional controls and deed restrictions. Future land use of adjoining properties probably will continue to be of a recreational nature. The ponds and sloughs surrounding the French Limited site could be used for boating, fishing, and swimming. The higher elevation land to the east of the site could be used for residential or commercial development. Any new development may involve the use of groundwater as a drinking water supply or for use in irrigation. Sand mining in the area is also a possible future land use.

2.8.4 Subpopulations of Potential Concern

The potential for pathways of exposure to sensitive subpopulations exists given the presence of residential areas (primarily the Riverdale Subdivision) near the French Limited site. Subpopulations that may be more sensitive to chemical exposures include infants and children, elderly people, pregnant and nursing women, and people with chronic illnesses. In the context of DNAPL-associated exposure pathways, all of these groups are considered to have equal potential for exposure through the direct or indirect consumption of contaminated drinking water.

3.0 EXPOSURE ASSESSMENT

This section of the report describes the Exposure Assessment component of the Risk Evaluation process for DNAPL-impacted areas of the French Limited site. The objective of the exposure assessment is to estimate the type and magnitude of exposures to the chemicals of potential concern that are present at, or migrating from, the DNAPL-impacted areas of the site. The results of the exposure assessment are combined with chemical-specific toxicity information (Section 4.0) to characterize potential risks (Section 5.0). Definitions used in this section of the report are included at the beginning of the report text.

3.1 Background

Exposure is defined as the contact of an organism (humans in the case of health risk evaluation) with a chemical or physical agent (EPA, 1988b,c). The magnitude of exposure is determined by measuring or estimating the amount of an agent available at the exchange boundaries (i.e., the lungs, gut, skin) during a specified time period. Exposure assessment is the determination or estimation (qualitative or quantitative) of the magnitude, frequency, duration, and route of exposure The exposure assessment conducted for this particular investigation will not consider past exposures but will concentrate on present and future exposures.

3.2 Components of an Exposure Assessment

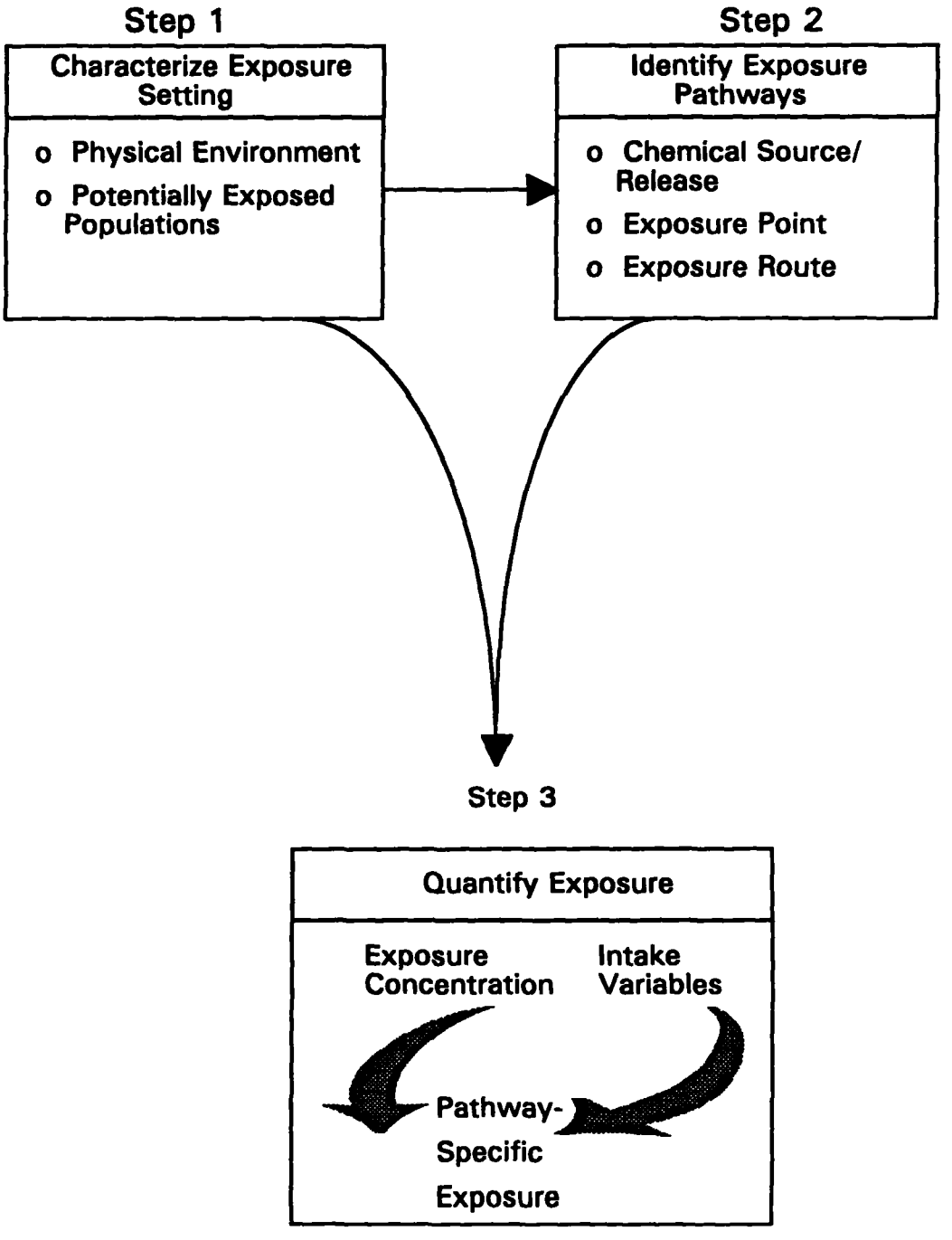
The general procedure for conducting an exposure assessment is illustrated in Figure 3-1. The exposure assessment consists of three components:

1. Characterization of exposure setting
2. Identification of exposure pathways
3. Quantification of exposure

These steps in the Exposure Assessment process are briefly described in the following sections.

FIGURE 3-1

The Exposure Assessment Process



3.2.1 Characterization of Exposure Setting

The first step of the exposure assessment process is to characterize the exposure setting of the French Limited site and the nearby populations. This characterization is described in Section 2.0 of this report. The exposure setting description includes basic site characteristics such as climate, vegetation, groundwater and surface water hydrology. Potentially exposed populations also are identified and are described with respect to characteristics that influence exposure, such as location relative to the site, activity patterns, and presence of sensitive subpopulations. This step considers the characteristics of the current population, as well as those of any potential future populations that may differ under an alternate land use.

3.2.2 Identification of Exposure Pathways

In this second step, the exposure pathways by which the previously identified populations may be exposed are identified. Each exposure pathway describes a unique mechanism by which a population may be exposed to the chemicals at, or originating from, DNAPL-impacted areas of the site. Exposure pathways are identified based on:

- consideration of the sources, releases, types, and locations of chemicals in the DNAPL-impacted areas of the site;
- the likely environmental fate (including persistence, partitioning, transport, and intermedia transfer) of these chemicals;
- the location and activities of the potentially exposed populations.

Exposure points (points of potential contact with the chemical) and routes of exposure (e.g., ingestion, inhalation) are identified for each exposure pathway.

3.2.3 Quantification of Exposure

In this third step of the exposure assessment, the magnitude, frequency and duration of exposure for each identified pathway is quantified. This step is conducted in two stages: estimation of exposure concentrations and calculation of intakes.

Estimation of Exposure Concentrations

In this part of Step 3, the concentration of chemicals that may be contacted over the exposure period are determined. Exposure concentrations are estimated using monitoring data and/or chemical transport and environmental fate models. Modeling is used to estimate future chemical concentrations in media that are currently contaminated or that may become contaminated, and current concentrations in media and/or at locations for which there are no monitoring data.

Calculation of Intakes

In this part of Step 3, the chemical-specific exposures for each identified exposure pathway are calculated. For the human health exposure assessment, exposure estimates are expressed in terms of the mass of substance in contact with the body per unit body weight per unit time (e.g., mg chemical per kg body weight per day, also expressed as mg/kg-day). These exposure estimates are termed "intakes" and represent the normalized exposure rate. Chemical intakes are calculated using equations that include variables for exposure concentration, contact rate, exposure frequency, exposure duration, body weight, and exposure averaging time. The values of some of these variables depend on site conditions and the characteristics of the potentially exposed population.

After intakes have been estimated, they are organized by population, as appropriate. Then, the sources of uncertainty (e.g., variability in analytical data, modeling results, parameter assumptions) and their effect on the exposure estimates are evaluated and summarized. The exposure assessment concludes with a summary of the estimated intakes for each pathway evaluated.

3.3 Reasonable Maximum Exposure

The Risk Evaluation associated with DNAPL occurrence at the French Limited site is based on an estimate of the reasonable maximum exposure (RME) expected to occur under both current and future land-use conditions. The reasonable maximum exposure is defined here as the highest exposure that is reasonably expected to occur at the site. RMEs are estimated for individual pathways. If a population is exposed via more than one pathway, the combination of exposures across pathways also must represent an RME. The intent of the RME is to estimate a conservative exposure case (i.e., well above the average case) that is still within the range of possible exposures. The variation in individual exposure variables is used to evaluate uncertainty. In this way, the variables contributing most to uncertainty in the exposure estimate are more easily identified.

3.4 Characterization of Exposure Setting

The exposure setting of the French Limited site and nearby populations is described in Section 2.0 of this report. This forms the basis of discussion for exposure pathways and quantification of exposure.

3.5 Identification of Exposure Pathways

The exposure pathway describes the course a chemical or physical agent takes from the source to the exposed individual. The analysis of the exposure pathway links the sources, locations, and types of environmental releases with population locations and activity patterns to determine the significant pathways of human exposure.

Exposure pathways consist of the following four elements:

1. a source and mechanism of chemical release,
2. a retention or transport medium (or media in cases involving media transfer of chemicals),
3. a point of potential human contact with the contaminated medium (referred to as the exposure point),
4. an exposure route (e.g., ingestion) at the contact point.

For this Risk Evaluation, the "contaminant source" at the French Limited site is the DNAPL itself and soils directly impacted by DNAPL. These contaminated media act as sources for groundwater contamination which may in turn may contaminate surface water. Groundwater is considered the transport medium. In some exposure scenarios, such as dermal contact during excavation and drilling activities, the DNAPL source itself is the exposure point, without a release to any other medium. In these latter cases, the exposure pathway consists of (1) the source, (2) the exposure point, and (3) the exposure route.

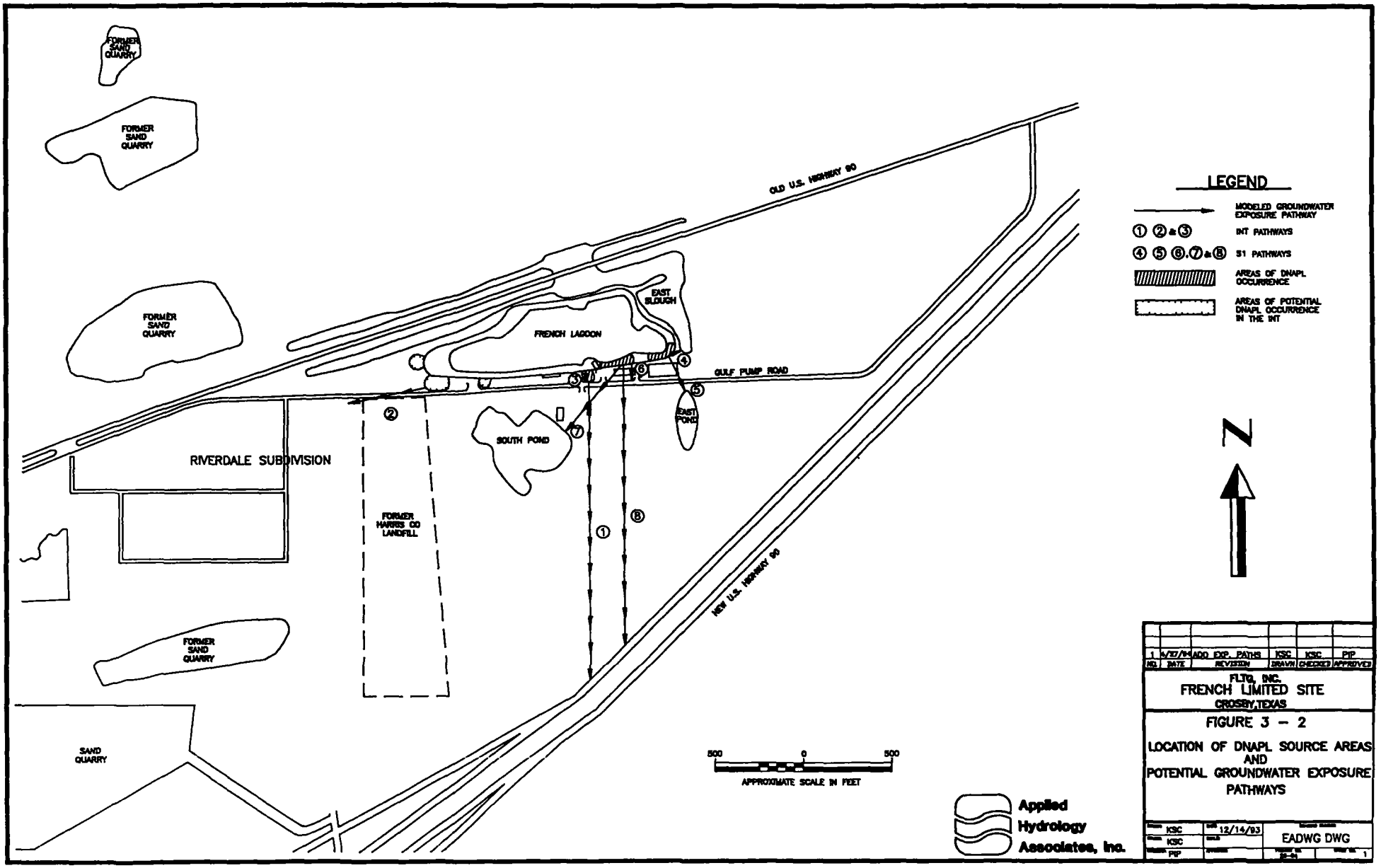
3.5.1 DNAPL Sources and Receiving Media

Three distinct areas of DNAPL contamination of subsoils at the French Limited site were identified and characterized in the *DNAPL Study Field Data Report* (AHA, 1993b). Figures 2-2 and 3-2 show the location and the extent of DNAPL contamination within these areas. In both the S1-13 and S1-16 areas, DNAPL-contaminated subsoils are limited in extent to the S1 unit within the sheetpile wall. In the INT-11 area, DNAPL has only been observed in the INT unit and was found to extend outside the sheetpile wall to just north (approximately 5 to 10 feet) of Gulf Pump Road. In this area, the southernmost portion of the DNAPL contamination appears to be non-mobile, having been identified in soil borings, but not in subsequently completed monitoring wells.

All three DNAPL areas have groundwater containing constituents distinctive of DNAPL composition as a result of solubilization and leaching of DNAPL-impacted soils. The DNAPL-impacted groundwater extends outside the sheetpile wall in all three areas. In the case of the S1-13 and S1-16 areas, contaminated groundwater has been detected in both the S1 and INT units. In the INT-11 area, groundwater contamination has been observed in monitoring wells screened in the INT unit. The absence of a continuous C1 clay in this area and presence of high total organic carbon (TOC) measured in nearby S1 production wells suggests that groundwater contamination occurs in both the S1 and INT units in this area.

In addition to the three areas of known DNAPL occurrence, there are areas of potential DNAPL occurrence suggested by high concentrations of characteristic DNAPL chemicals in groundwater. In particular, the INT unit in the western part of the site (the INT West Area of Figure 2-2) is a suspected DNAPL-impacted area although there is no direct evidence of actual DNAPL occurrence. From a Risk Evaluation standpoint, highly contaminated soils, whether they actually contain DNAPL or not, provide a "source" for groundwater contamination. Consequently, for completeness, the INT-West potential DNAPL area is included in the Risk Evaluation.

All observed instances of DNAPL contamination at the French Limited site occur north of Gulf Pump Road and within the area currently controlled by FLTG, Inc. at depths of no less than 27 feet in the S1 unit and no less than 38 feet in the INT unit. The most likely present and future route of direct DNAPL exposure is during drilling and excavation activities associated with site investigations or remediation. Workers involved with these activities are required to have health and safety training (29 CFR 1910.120) so that they are knowledgeable in the use of safety measures and personal protective equipment to prevent potential exposures.


FORMER SAND QUARRY
FORMER SAND QUARRY
FORMER SAND QUARRY
FORMER SAND QUARRY
OLD U.S. HIGHWAY 90
EAST SLOUGH
FRENCH LAGOON
GULF PUMP ROAD
EAST POND
SOUTH POND
RIVERDALE SUBDIVISION
FORMER HARRIS CO LANDFILL
NEW U.S. HIGHWAY 90
SAND QUARRY
LEGEND
MODELED GROUNDWATER EXPOSURE PATHWAY
① ② & ③ INT PATHWAYS
④ ⑤ ⑥, ⑦ & ⑧ S1 PATHWAYS
AREAS OF DNAPL OCCURRENCE
AREAS OF POTENTIAL DNAPL OCCURRENCE IN THE INT
N
500 0 500
APPROXIMATE SCALE IN FEET
Applied Hydrology Associates, Inc.
1 4/27/94 ADD EXP. PATHS KSC KSC PIP
NO. DATE REVISION DRAWN CHECKED APPROVED
FLTG, INC.
FRENCH LIMITED SITE
CROSBY, TEXAS
FIGURE 3 - 2
LOCATION OF DNAPL SOURCE AREAS AND POTENTIAL GROUNDWATER EXPOSURE PATHWAYS
KSC 12/14/93 EADWG DWG
KSC
PIP

Potentially, such DNAPL-impacted strata could be encountered during a future excavation for a building foundation by workers not specifically trained to handle potentially hazardous chemicals. This exposure pathway is, however, not realistic in light of local building practices and site conditions. In particular, there is no indication of DNAPL-impacted soils south of Gulf Pump Road, which is the closest location that a building could be constructed outside FLTG property. In addition, the presence of a shallow water table discourages deep excavations for foundations. The current local building practice is to install shallow concrete slabs, rather than deep piers, to provide building support. The potential exposure from accumulation and subsequent inhalation of compounds volatilized from DNAPL in basements or deep excavations is again prevented by local building practice which prohibits the construction of such structures due to the shallow water table .

Direct exposure to DNAPL and DNAPL-impacted soils via dermal contact, incidental ingestion or inhalation of volatilized compounds is thus controlled or prevented by local conditions and are not considered realistic potential exposure pathways in this Risk Evaluation.

3.5.2 Fate and Transport in Release Media

The fate and transport of the chemicals associated with DNAPL-impacted areas of the French Limited site were evaluated to predict future exposures and to help link sources with currently contaminated media. The intent is to identify media that are receiving or may receive chemicals related to the DNAPL-impacted areas of the site.

In determining the fate of the chemicals of potential concern at the site, information on their physical/chemical and environmental fate properties were compiled. Computer data bases and the open literature were used, as necessary, as sources for up-to-date information on the physical/chemical and fate properties of the chemicals of potential concern. Table 3-1 lists some important chemical-specific fate parameters and briefly describes how these are used to evaluate a chemical's environmental fate.

Under both active remediation and passive non-treatment scenarios, the primary transport media for DNAPL chemicals is groundwater. Advective transport under natural or imposed hydraulic gradients is the primary migration mechanism. The groundwater receives chemicals related to the DNAPL-impacted areas of the French Limited site as a result of leaching and solubilization of DNAPL and DNAPL-impacted soils. The major chemicals that are characteristic of the DNAPL areas are the chlorinated solvents including: carbon tetrachloride; 1,2 dichloroethane (DCA); chloroform; and 1,2 dichloroethene (DCE). Vinyl chloride is a breakdown product of higher chlorinated ethanes and occurs as a major constituent in groundwater.

TABLE 3-1

Important Physical/Chemical and Environmental Fate Parameters

K_{oc}	Provides a measure of the extent of chemical partitioning between organic carbon and water at equilibrium The higher the K_{oc}, the more likely a chemical is to bind to soil or sediment than to remain in water
K_d	Provides a soil or sediment-specific measure of the extent of chemical partitioning between soil or sediment and water, unadjusted for dependence upon organic carbon To adjust for the fraction of organic carbon present in soil or sediment (f_{oc}), use $K_d = K_{oc} \times f_{oc}$ The higher the K_d, the more likely a chemical is to bind to soil or sediment than to remain in water
K_{ow}	Provides a measure of the extent of chemical partitioning between water and octanol at equilibrium The greater the K_{ow} the more likely a chemical is to partition to octanol than to remain in water Octanol is used as a surrogate for lipids (fat), and K_{ow} can be used to predict bioconcentration in aquatic organisms
Solubility	The upper limit on a chemical's dissolved concentration in water at a specified temperature Aqueous concentrations in excess of solubility may indicate sorption onto sediments, the presence of solubilizing chemicals such as solvents, or the presence of a non-aqueous phase liquid
Henry's Law Constant	Provides a measure of the extent of chemical partitioning between air and water at equilibrium The higher the Henry's Law constant, the more likely a chemical is to volatilize than to remain in the water
Vapor Pressure	The pressure exerted by a chemical vapor in equilibrium with its solid or liquid form at any given temperature It is used to calculate the rate of volatilization of a pure substance from a surface or in estimating a Henry's Law constant for chemicals with low water solubility The higher the vapor pressure, the more likely a chemical is to exist in a gaseous state
Diffusivity	Describes the movement of a molecule in a liquid or gas medium as a result of differences in concentration It is used to calculate the dispersive component of chemical transport The higher the diffusivity, the more likely a chemical is to move in response to concentration gradients
Bioconcentration Factor (BCF)	Provides a measure of the extent of chemical partitioning at equilibrium between a biological medium (e g fish tissue or plant tissue) and an external medium (e g water) The higher the BCF, the greater the likely accumulation in living tissue
Media-specific Half-life	Provides a relative measure of the persistence of a chemical in a given medium, although values can very greatly depending on site-specific conditions The greater the half-life, the more persistent a chemical is likely to be

The basic chemical and physical properties of the constituents detected in subsurface media are summarized in Table 3-2. In general, the chlorinated organic constituents typically associated with DNAPL-impacted soils and groundwater at the French Limited site, as noted above, have the following characteristics:

- fairly soluble,
- low adsorptive tendencies,
- biodegrade very slowly under normal (non-stimulated) conditions,
- degrade to less-chlorinated compounds by reductive dehalogenation process,
- volatilize readily if exposed to atmospheric conditions,
- do not tend to bio-accumulate.

A screening level analysis, considering the characteristics of the chlorinated solvent constituents, indicates that relatively little retardation will likely occur in the S1 unit. The INT unit has the ability to retard the migration of organic constituents in groundwater, but removal of constituents by natural degradation or volatilization processes will be very slow. Consequently, transport of these constituents in groundwater is considered to be dominated by advection.

Under the operating remedial system, surface water bodies tend to act as recharge sources for the groundwater. However, under non-operating conditions, surface water within ponds and sloughs around the French Limited site may receive discharge of groundwater. Consequently, under a scenario of future non-operational conditions, with DNAPL-impacted "source" areas still existing, a surface water pathway could exist via discharge of contaminated groundwater to ponds and sloughs. Because the ponds tend to penetrate only into the upper part of the S1 unit, the surface water pathway is restricted to discharge of S1 groundwater.

TABLE 3-2

Chemical and Physical Properties of Constituents Detected in Subsurface Media

Chemical Compound	CAS #	Molecular Weight (g/mole)	Water Solubility (mg/L)	Vapor Pressure (mm Hg) (1)	Henry's Law Constant (atm-m3/mol)	K_{oc} (ml/g) (2)	Log K_{ow} (3)	Fish BCF (L/kg) (4)	Surface Water Half-Life (days)	Kp Value (cm/hr) (5)	Ref.
VOLATILES											
chloromethane	74-87-3	50	6 50E+3	4 31E+3	4 40E-2	35	0 95	----	1	4 2E-3	A
vinyl chloride	75-01-4	63	2 67E+3	2 66E+3	8 19E-2	57	1 38	1 17	1-5	7 24E-3	A
chloroethane	75-00-3	65	5 71E+3	7 66E+2 (@12 5 C)	8 48E-3	----	1 43	7 2	1 1-5 6	8 0E-3	B2
methylene chloride	75-09-2	85	2 00E+4	3 62E+2	2 03E-3	8 8	1 30	5	1 2-5 8	5 62E-3	A
acetone	67-64-1	58	miscible	2 70E+2	2 06E-5	2 2	-0 24	----	----	----	A
1,1-dichloroethene	75-35-4	97	2 25E+3	6 00E+2	3 40E-2	65	1 84	5 6	1-6	9 55E-3	A
1,1-dichloroethane	75-34-3	99	5 50E+3	1 82E+2	4 31E-3	30	1 79	----	1-5	4 57E-2	A
cis-1,2-dichloroethene	156-59-2	97	3 50E+3	2 08E+2	7 58E-3	49	0 50	1 6	1-6	1 0E-2	A
trans-1,2-dichloroethene	156-60-5	97	6 30E+3	3 24E+2	6 56E-3	59	0 48	1 6	1-6	1 0E-2	A
chloroform	67-66-3	119	8 20E+3	1 51E+2	2 87E-3	31	1 97	3 75	0 3-30	2 95E-2	A
1,2-dichloroethane	107-06-2	99	8 52E+3	6 40E+1	9 78E-4	14	1 48	1 2	0 17	1 95E-2	A
2-butanone	78-93-3	72	2 68E+5	7 75E+1	2 74E-5	4 5	0 26	0 0	10	6 17E-4	A
carbon tetrachloride	56-23-5	154	7 57E+2	9 00E+1	2 41E-2	110	2 64	19	0 3-300	2 14E-3	A
vinyl acetate	108-05-4	86	2 00E+4	8 50E+1	4 81E-4	----	0 73	2 3	2 2-13	----	B1
trichloroethene	79-01-6	131	1 10E+3	5 79E+1	9 10E-3	126	2 38	10 6	1-90	8 32E-2	A
1,1,2-trichloroethane	79-00-5	133	4 50E+3	3 00E+1	1 17E-3	56	2 47	5	1 9	8 4E-3	A
benzene	71-43-2	78	1 75E+3	9 52E+1	5 59E-3	83	2 12	5 2	1-6	4 27E-2	A
4-methyl-2-pentanone	108-10-1	100	2 04E+4	1 45E+1	9 40E-5	----	1 19	5	0 6-1 4	4 90E-3	B2
tetrachloroethene	127-18-4	166	1 50E+2	1 78E+1	2 59E-2	364	2 6	31	1-30	7 94E-3	A
1,1,2,2-tetrachloroethane	79-34-5	168	2 90E+3	5 00E+0	3 81E-4	118	2 39	42	0 04	9 0E-3	A
toluene	108-88-3	92	5 35E+2	2 81E+1	6 37E-3	300	2 73	10 7	0 17	1 70E-1	A
ethylbenzene	100-41-4	106	1 52E+2	7 00E+0	6 43E-3	1,100	3 15	37 5	1 5-7 5	4 47E-1	A
xylene	1330-20-7	106	1 98E+2	1 00E+1	7 04E-3	240	3 26	----	1 5-9	8 0E-2	A

(1) Vapor pressure at 20-30 degrees Celsius
(2) K_{oc} = Equilibrium partition coefficient between organic carbon and water
(3) K_{ow} = Equilibrium partition coefficient between octanol carbon and water
(4) BCF = Bio-Concentration Factor (Equilibrium chemical partition coefficient between fish tissue and water)
(5) Kp = Dermal Permeability Constants (Values are from EPA, 1991d, Interim Guidance for Dermal Exposure Assessment
NA = Not Applicable
A = EPA Superfund Public Health Evaluation Manual, Oct 1986
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TABLE 3-2 (Cont.)

Chemical and Physical Properties of Constituents Detected in Subsurface Media

Chemical Compound	CAS #	Molecular Weight (g/mole)	Water Solubility (mg/L)	Vapor Pressure (mm Hg) (1)	Henry's Law Constant (atm-m3/mol)	K_{oc} (ml/g) (2)	Log K_{ow} (3)	Fish BCF (L/kg) (4)	Surface Water Half-Life (days)	Kp Value (cm/hr) (5)	Ref.
SEMI-VOLATILES											
phenol	108-95-2	94	9 30E+4	3 41E-1	4 54E-7	14 2	1 46	1 4	0 62-9	5 5E-3	A
2-methylphenol	95-48-7	108	3 08E+1	3 10E-1	1 60E-6	----	1 95	18	2	----	B1
4-methylphenol	106-44-5	108	2 26E+1	1 30E-1	9 60E-7	----	1 94	18	0 5-6	----	B1
hexachloroethane	67-72-1	237	5 00E+1	4 00E-1	2 49E-3	20,000	4 60	87	1 1-9 5	4 2E-2	A
2,4-dimethylphenol	105-67-9	122	6 20E+3	9 80E-2	6 30E-7	----	2 30	1 18	----	8 51E-5	B1
1,2,4-trichlorobenzene	120-82-1	181	3 00E+1	2 90E-1	2 31E-3	9,200	4 30	2,800	1 2	3 02E-2	A
naphthalene	91-20-3	128	3 17E+1	8 20E-2	4 83E-4	----	3 30	1,000	1-9	6 31E-1	B1
hexachlorobutadiene	87-68-3	261	1 50E-1	2 00E+0	4 57E+0	29,000	4 78	2 8	29-2,300	1 2E-1	A
2-methylnaphthalene	91-57-6	---	2 54E+1	----	3 31E-4	7,940	4 11	----	----	----	----
acenaphthylene	208-96-8	152	3 93E+0	2 90E-2	1 48E-3	2,500	3 70	----	0 125	----	A
acenaphthene	83-32-9	154	3 42E+0	1 55E-3	9 20E-5	4,600	4 00	242	----		A
dibenzofuran	132-64-9	168	----	----	----	----	----	----	28	----	----
fluorene	86-73-7	116	1 69E+0	7 10E-4	6 42E-5	7,300	4 20	1,300	1-2	----	A
hexachlorobenzene	118-74-1	285	6 00E-3	1 09E-5	6 81E-4	3,900	5 23	8,690	0 3-300	2 1E-1	A
phenanthrene	85-01-8	178	1 00E+0	6 80E-4	1 59E-4	14,000	4 46	2,630	0 38-2	2 7E-1	A
anthracene	120-12-7	178	4 50E-2	1 95E-4	1 02E-3	14,000	4 45	----	----	----	A
fluoranthene	206-44-0	202	2 06E-1	5 00E-6	6 46E-6	38,000	4 90	1,150	1-2	3 6E-1	A
pyrene	129-00-0	202	1 32E-1	2 50E-6	5 04E-6	38,000	4 88	----	----	----	A
benzo(A)anthracene	56-55-3	228	5 70E+3	2 20E-8	1 16E-6	138,000	5 60	----	0 1-5	8 1E-1	A
bis(2-ethylhexyl)phthalate	117-81-7	391	3 00E-1	6 45E-6	1 10E-5	----	5 11	2-4	14-21	----	B1
chrysene	218-01-9	228	1 80E-3	6 30E-9	1 05E-6	200,000	5 61	----	0 2	8 1E-1	A
benzo(B)fluoranthene	205-99-2	252	1 40E-2	5 00E-7	1 19E-5	550,000	6 06	----	1-2	1 2E+0	A
benzo(A)pyrene	50-32-8	252	1 20E-3	5 60E-9	1 55E-6	550,000	6 06	----	0 4	1 2E+0	A
indeno(1,2,3-CD)pyrene	193-39-5	276	5 30E-4	1 00E-10	6 86E-8	160,000	6 50	----	0 02-2 08	1 9E+0	A
dibenzo(A,H)anthracene	53-70-3	278	5 00E-4	1 00E-10	7 33E-8	330,000	6 80	----	0 02-2 08	2 7E+0	A
benzo(GHI)perylene	191-24-2	276	7 00E-4	1 03E-10	5 34E-8	160,000	6 51	----	----	----	A

(1) Vapor pressure at 20-30 degrees Celsius
(2) K_{oc} = Equilibrium partition coefficient between organic carbon and water
(3) K_{ow} = Equilibrium partition coefficient between octanol carbon and water
(4) BCF = Bio-Concentration Factor (Equilibrium chemical partition coefficient between fish tissue and water)
(5) Kp = Dermal Permeability Constants (Values are from EPA, 1991a, Interim Guidance for Dermal Exposure Assessment
NA = Not Applicable
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TABLE 3-2 (Cont.)

Chemical and Physical Properties of Constituents Detected in Subsurface Media

Chemical Compound	CAS #	Molecular Weight (g/mole)	Water Solubility (mg/L)	Vapor Pressure (mm Hg (1))	Henry's Law Constant (atm-m3/mol)	K_{oc} (ml/g) (2)	Log K_{ow} (3)	Fish BCF (L/kg) (4)	Surface Water Half-Life (days)	Kp Value (cm/hr) (5)	Ref.
PESTICIDES											
alpha-BHC	319-84-6	291	2 00E-3	4 50E-5	1 06E-5	—	3 80	—	—	—	B3
beta-BHC	319-85-7	291	2 40E-1	2 80E-7	4 47E-7	3,800	3 90	130	—	—	
delta-BHC	319-86-8	291	3 14E+1	1 70E-5	2 07E-7	6,600	4 10	130	—	—	
gamma-BHC (lindane)	58-89-9	291	7 80E 0	1 60E-4	7 85E-6	1,080	3 90	130	—	1 4E-2	
aldrin	309-00-2	365	1 80E-1	6 00E-4	1 60E-5	9 60E+4	5 30	28	—	1 6E-3	
4,4-DDE	72-55-9	318	4 00E-2	6 00E-6	6 80E-	4 40E+6	7 00	51	—	2 4E-1	
endrin	72-20-8	381	2 50E-4	3 00E-6	7 52E-6	3 40E+4	4 56	1 3-10E+4	10d-14y	1 6E-2	B3
endrin aldehyde	7421-93-4	—	—	—	—	—	—	—	—	—	
heptachlor	76-44-8	374	1 80E-1	3 00E-4	8 19E-4	12,000	5 27	3,800-3,7000	1-5	1 1E-2	B3
PCB (Total)	1336-36-3	328	3 10E-2	7 70E-5	1 07E-3	530,000	6 04	100,000	2-12 9	7 1E-1 to 1 3E+0	
METALS											
arsenic	7440-38-2	75	—	0	NA	NA	N/A	44	—	3 16E-4	A
chromium	7440-47-3	52	—	0	NA	NA	N/A	16	>3 Days	1 0E-3	
copper	7440-05-8	64	—	0	NA	NA	N/A	200	—	1 0E-3	
zinc	7440-66-6	65	—	0	NA	NA	N/A	47	Persistent	6 0E-4	

(1) Vapor pressure at 20-30 degrees Celsius
(2) K_{oc} = Equilibrium partition coefficient between organic carbon and water
(3) K_{ow} = Equilibrium partition coefficient between octanol carbon and water
(4) BCF = Bio-Concentration Factor (Equilibrium chemical partition coefficient between fish tissue and water)
(5) Kp = Dermal Permeability Constants (Values are from EPA, 1991d, Interim Guidance for Dermal Exposure Assessment
NA = Not Applicable
A = EPA Superfund Public Health Evaluation Manual, Oct 1986
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3.5.3 Exposure Points, Routes and Pathways

The primary exposure pathways for contact of potentially exposed populations with contaminated media are shown on Figure 3-2 and are summarized as follows:

1. Exposure of residential populations to potentially contaminated groundwater in the Upper Alluvial Zone downgradient from the site. Exposure could be from ingestion of contaminated groundwater or inhalation of vapors from contaminated water during showering. The closest current potential exposure points are existing domestic wells located in the Riverdale Subdivision, southwest of the site and potential wells located south of the new Highway 90 (Crosby Freeway). The closest future exposure point could be a domestic well immediately north of Gulf Pump Road.

2. Exposure of residential population to surface water that could potentially receive contaminated groundwater discharge. Exposure could be from dermal contact or casual ingestion of water in ponds during swimming or ingestion of contaminated fish tissue. The closest current (and future) exposure points are the South and East Ponds, and the East Slough.

For purposes of this Risk Evaluation, no institutional controls or deed restrictions that would prevent future residential development or groundwater supply wells have been assumed for the property between Gulf Pump Road and the new Highway 90 (Crosby Freeway). Currently, this property is secure and under lease to FLTG so that there is no current exposure potential to either surface water or groundwater pathways. The area is subject to Risk Evaluation for future potential surface water and groundwater pathways.

Under the current conditions of active remedial operations at the site, groundwater migration in the vicinity of the site is controlled. Accordingly, no migration of potentially contaminated groundwater can occur to the exposure points noted above. These potential exposure points, therefore, only apply to potential future conditions when the remedial system is no longer operating, assuming the source of DNAPL-impacted soils still exists and is not contained, and hydraulic gradients are such that groundwater migration to these exposure points can occur.

As noted above, direct dermal contact or inhalation of DNAPL constituents as a result of drilling operations on site is not considered in this Risk Evaluation because these activities are performed under closely controlled and monitored conditions. In addition, as noted above, local building practice and a shallow water table precludes deep excavation for building foundations so that direct dermal contact or inhalation of DNAPL constituents as a result of these activities is not considered in this Risk Evaluation. All areas of known current DNAPL occurrence or future DNAPL occurrence are located north of Gulf Pump Road and within the area currently controlled by FLTG, Inc. and are, therefore, not accessible to uncontrolled drilling or excavation activities.

3.6 Quantification of Exposure

The final step in the Exposure Assessment involves quantifying the magnitude, frequency and duration of exposure for the populations and exposure pathways selected for quantitative evaluation. This step is reported in two stages: first, an estimate of exposure concentrations, and second, quantification of pathway-specific intakes.

3.6.1 Quantification of the Reasonable Maximum Exposure

Exposure is defined as the contact of an organism with a chemical or physical agent. If exposure occurs over time, the total exposure can be divided by a time period of interest to obtain an average exposure rate per unit time. This average exposure rate also can be expressed as a function of body weight. Exposure normalized for time and body weight is termed "intake", and is expressed in units of mg chemical/kg body weight-day (Table 3-3).

Three categories of variables are used to estimate intake:

1. chemical-related variable -- exposure concentration;

2. variables that describe the exposed population -- contact rate, exposure frequency and duration, and body weight;

3. assessment-determined variable -- averaging time.

Each intake variable has a range of values associated with DNAPL-impacted media at the French Limited site. Intake variable values for a given pathway have been selected so that the combination of all intake variables results in an estimate of the reasonable maximum exposure (RME) for that pathway. The RME is the maximum exposure that is reasonably expected to occur for any given exposure route. Some intake variables may not be at their individual maximum values but when in combination with other variables will result in estimates of the RME.

A more detailed explanation of each of the variables used in the calculation of chemical intake as expressed in Table 3-3 is given in the following sections.

TABLE 3-3

General Equation for Calculating Chemical Intakes

$$I = C \times \frac{CR \times EFD}{BW} \times \frac{1}{AT}$$

Where:

I = intake; the amount of chemical at the exchange boundary (mg/kg body weight-day)

Chemical-related variable

C = chemical concentration, the average concentration contacted over the exposure period (e g , mg/liter water)

Variables that describe the exposed population

CR = contact rate; the amount of contaminated medium contacted per unit time or event (e g , liters/day)

EFD = exposure frequency and duration, describes how long and how often exposure occurs. Often calculated using two terms (EF and ED)

EF = exposure frequency (days/year)
ED = exposure duration (years)

BW = body weight; the average body weight over the exposure period (kg)

Assessment-determined variable

AT = averaging time; period over which exposure is averaged (days)

Exposure concentration - The exposure concentration is the arithmetic average of the measured or projected concentration that is contacted over the exposure period. Although this concentration does not reflect the maximum concentration that could be contacted at any one time, it is regarded as a reasonable estimate of the concentration likely to be contacted over time. In most situations, it is not reasonable to assume long-term contact with the maximum concentration. The upper confidence limit (i.e., the 95 percent upper confidence limit) of the arithmetic average was used for this variable because of the uncertainty associated with any estimate of exposure concentration. In this Risk Evaluation, all exposure concentrations were projected by modeling and mass-balance calculations.

Contact rate - Contact rate reflects the amount of contaminated medium contacted per unit time or event. If statistical data are available for a contact rate, the 95th percentile value for this variable was used. If statistical data were not available, professional judgment was used to estimate a value which approximates the 95th percentile value.

Exposure frequency and duration - Exposure frequency and duration was used to estimate the total time of exposure. These terms were determined based on the site characteristics. If statistical data were available, the 95th percentile value for exposure time was used. In the absence of statistical data, reasonable conservative estimates of exposure time were used.

Body weight - The value for body weight is the average body weight over the exposure period. The average body weight is used because, when combined with the other variable values in the intake equation, it is believed to result in the best estimate of the RME.

Averaging time - The averaging time selected depends on the type of toxic effect being evaluated. In this Risk Evaluation, a 70 year lifetime was assumed for chronic exposure calculations. Exposures to a developmental toxicant are typically evaluated and intakes calculated by averaging over the exposure event (e.g., a day or a single exposure incident). For acute toxicants, intakes are typically calculated by averaging over the shortest exposure period that could produce an effect, usually an exposure event or a day. In this Risk Evaluation, exposure to acute and developmental toxicants were assessed by comparison of calculated maximum exposure concentrations to 10-day and 1-day health advisories for the chemicals of concern.

3.6.2 Timing Considerations

Long term exposure to relatively low chemical concentrations (i.e., chronic daily intakes) is of greatest concern. Shorter-term exposure (i.e., subchronic daily intakes) is also important. The following factors were considered in the evaluation of short-term exposure.

- the toxicological characteristics of the chemicals of potential concern;
- the occurrence of high chemical concentrations or the potential for a large release;
- persistence of the chemical in the environment;
- the characteristics of the population that influence the duration of exposure.

Toxicity considerations - Some chemicals can produce an effect after a single or very short-term exposure to relatively low concentrations. These chemicals include acute toxicants such as skin irritants and neurological poisons, and developmental toxicants. Several of the chemicals identified at the site display evidence of these types of toxicological characteristics. For these toxicants, exposure over both a one-day and ten-day period was evaluated. These time periods were chosen because they are appropriate for this type of toxicological exposure, and the calculated exposure concentrations could be compared with one-day and ten-day health advisory values for specific chemicals as described in Sections 4.0 and 5.0.

Concentration considerations - Many chemicals can produce an effect after a single or very short-term exposure, but only if exposure is to a relatively high concentration. Identification of possible situations where a short-term exposure to high concentration occurrence were assessed. For these situations, exposure was evaluated over both a one-day and ten-day period.

Persistence considerations - Some chemicals may degrade rapidly in the environment. In these cases, exposure may be assessed only for that period of time in which the chemical is likely to be present at the site. In this Risk Evaluation, for conservative calculations, no degradation of chemicals was assumed, but exposure to known breakdown products, e.g. vinyl chloride, was considered.

Population considerations - If population activities are such that exposure would occur only for a short time period (a few weeks or months), infrequently, or intermittently, these periods of time are averaged and assessed. For example, the surface water exposure scenarios assumed a conservatively high 30 swimming events per year over a 30 year time frame.

3.6.3 Determination of Exposure Concentrations

The basic approach and methodology for determining exposure concentrations of chemicals of concern at the site is described below. The chemicals of concern are based on screening of chemical constituents identified at the site on the basis of toxicological characteristics (Section 4.0) and fate and transport considerations.

Exposure concentrations are calculated for the different environmental media using available monitoring data and appropriate models. The concentration term in the exposure equation (Table 3-3) is the average concentration projected to be contacted at the exposure point or points over the exposure period. When estimating exposure concentrations, a conservative estimate of this average concentration is generally used (e.g., the 95 percent upper confidence limit of the arithmetic mean chemical concentration).

Estimate of Exposure Concentrations in Groundwater

Exposure concentrations of the groundwater were based on a combination of monitoring and modeling data. Data from monitoring wells were used to determine the maximum chemical concentrations in groundwater in each of the four potential DNAPL source areas at the French Limited site (Table 2-3). The location(s) used to evaluate groundwater exposure were selected on the basis of the closest point where a water supply well could be completed in the alluvial deposits and locations where such wells are already present. The closest possible future exposure point is immediately north of Gulf Pump Road. The Riverdale community and areas south of the new Highway 90 represent exposure points which currently exist or could exist at the present time.

Groundwater monitoring indicates that no current or past exposure to chemicals of concern in the groundwater has occurred. Current monitoring data indicates that contaminated groundwater has not migrated to existing potential exposure points. Sampling of domestic wells in the Riverdale subdivision by the EPA in December, 1987 did not find any indication of constituents that could have migrated from the French Limited site. Current operation of the groundwater remedial system prevents any further migration from the site by imposing hydraulic control on groundwater flows.

Modeling was used to estimate future contaminant concentrations at potential exposure points. The modeling assumed that operation of the current remedial system had ceased, but uncontained DNAPL "sources" still existed that continued to contaminate groundwater. These sources are assumed to exist in the S1 and INT units in the eastern part of the site, and only in the INT unit in the western part of the site, as shown on Figure 3-2. The modeling also assumed that a significant hydraulic gradient is imposed by some future activity, such as a gravel quarry dewatering operation, that would induce migration towards the receptor locations

Four transport scenarios were modeled for the groundwater exposure scenarios:

1. Transport of constituents in INT unit groundwater from the western part of the site to existing domestic wells in the Riverdale Subdivision

2. Transport of constituents in both S1 and INT unit groundwaters from the eastern part of the site to potential domestic wells south of the new Highway 90. The composite exposure concentration at the receptor is then based on the weighted average based on flow ratios from the two units.

3. Transport of constituents in INT unit groundwater from the eastern part of the site to hypothetical domestic wells immediately north of Gulf Pump Road.

4. Transport of constituents in S1 unit groundwater from the eastern part of the site to hypothetical domestic wells immediately north of Gulf Pump Road.

Details of the modeling assumptions are included in Appendix A. The results of the modeling are summarized in Appendix A and in Table 3-4. Inhalation exposure concentrations of chemicals that may volatilize from the contaminated groundwater, for example during showering, are calculated based on the dissolved water concentrations and volatilization constants for specific chemicals, as described under "Estimate of Exposure Concentrations in Air" below.

Estimate of Exposure Concentrations in Surface Water

Estimated groundwater discharge rates and concentrations, derived from fate and transport modeling were used to estimate surface water exposure concentrations. The modeling assumed that operation of the current remedial system had ceased, but uncontained DNAPL "sources" still existed at the S1-13 and S1-16 areas of the site. These source areas could continue to contribute to S1 unit groundwater contamination that could then discharge to the ponds. The maximum chemical concentrations in groundwater in these two DNAPL source areas are shown in Table 2-3. Only S1 unit discharges were considered as the existing ponds penetrate into the top of these units.

Two transport scenarios were modeled:

1. Transport of constituents in groundwater of the S1 unit from the S1-13 DNAPL area to the South Pond.

2. Transport of constituents in groundwater of the S1 unit from the S1-16 DNAPL area to the East Pond and the East Slough.

Details of the groundwater transport modeling assumptions and results are included in Appendix A. This modeling effort yields the projected maximum rate of constituent discharge into the ponds. The resulting surface water concentrations were then estimated by assuming total mixing with the pond water volume over a two year period. The results of the exposure concentration calculations are summarized in Appendix A and in Table 3-4.

Estimate of Exposure Concentrations in Fish Tissue

Chemical concentrations in fish can result from bioconcentration of chemicals in contaminated surface waters. Exposure to local residential populations occurs through ingestion of these fish. The fish tissue exposure concentrations are calculated based on the dissolved water concentrations and bioconcentration factors (BCF) for the various chemicals of concern (Table 3-2). The results of the exposure concentration calculations are summarized in Table 3-4.

Estimate of Exposure Concentrations in Soil

The DNAPL occurrence at the French Limited site is entirely below ground surface, at a depth below excavations for routine service maintenance (phone lines etc.). All areas of known current DNAPL occurrence or future DNAPL occurrence are located north of Gulf Pump Road and within the area currently controlled by FLTG, Inc. and are, therefore, not accessible to uncontrolled drilling or excavation activities. As noted above, direct dermal contact, ingestion or inhalation of DNAPL constituents as a result of excavation or drilling operations associated with remedial actions on site is not considered in this Risk Evaluation because these activities are performed under closely controlled and monitored conditions.

In addition, as noted above, local building practice and a shallow water table precludes deep excavation for building foundations so that a possible future exposure pathway, via direct dermal contact, ingestion or inhalation of DNAPL constituents during such activities, is not considered complete (no exposure) Therefore, direct dermal contact, ingestion or inhalation of DNAPL constituents is not considered in this Risk Evaluation.

Estimate of Exposure Concentrations in Air

Chemical concentrations in indoor air can result from volatilization of chemicals from contaminated domestic water supplies, for example during showering. Exposure to residential populations occurs through inhalation of air. The exposure concentrations are calculated based on the dissolved water concentrations and air/water partitioning coefficients (Henry's Law constants) for the chemicals of concern (Table 3-2). Details of these calculations are given in Appendix B-4. This exposure is considered under the groundwater pathway to residential wells. The results of the exposure concentration calculations are summarized in Table 3-4.

TABLE 3-4

Calculated Exposure Concentrations and Intake Dose Rates

Media: Groundwater
Exposed Population Residential
Exposure Pathway: Ingestion of affected groundwater that has migrated from the site to downgradient water supply wells
Exposure Time: Future

Chemical Compound	EXPOSURE POINT							
	North of Gulf Pump Road				Riverdale		South of New Hwy 90	
	from INT-11 Area		from S1-13 Area		from INT-West Area		from INT-11 & S1-13 Areas	
	Exposure Concentration (ug/L) (1)	Chronic Daily Intake (CDI) (mg/kg-day) (2)	Exposure Concentration (ug/L)	Chronic Daily Intake (CDI) (mg/kg-day)	Exposure Concentration (ug/L)	Chronic Daily Intake (CDI) (mg/kg-day)	Exposure Concentration (ug/L)	Chronic Daily Intake (CDI) (mg/kg-day)
vinyl chloride	6,000	7 3 E-2	7,278	8 9 E-2	16,000	2 0 E-1	6,639	8 1 E-2
methylene chloride	30,000	3 7 E-1	43,581	5 3 E-1	640	7 8 E-3	36,791	4 5 E-1
acetone	81,000	9 9 E-1	76,036	9 3 E-1	110,000	1 3 E+0	78,518	9 6 E-1
1,1-dichloroethene	1,800	2 2 E-2	1,137	1 4 E-2	160	2 0 E-3	1,469	1 8 E-2
1,1-dichloroethane	33,000	4 0 E-1	5,658	6 9 E-2	3,300	4 0 E-2	19,329	2 4 E-1
1,2-dichloroethene (total)	250,000	3 1 E+0	63,613	7 8 E-1	6,200	7 6 E-2	156,807	1 9 E+0
chloroform	850,000	1 0 E+1	131,131	1 6 E+0	250	3 1 E-3	490,566	6 0 E+0
1,2-dichloroethane	860,000	1 1 E+1	20,000	2 4 E-1	8,700	1 1 E-1	440,000	5 4 E+0
carbon tetrachloride	110,000	1 3 E+0	2	2 4 E-5	66	8 1 E-4	55,001	6 7 E-1
trichloroethene	6,500	8 0 E-2	18,957	2 3 E-1	680	8 3 E-3	12,729	1 6 E-1
1,1,2-trichloroethane	5	6 1 E-5	556	6 8 E-3	550	6 7 E-3	281	3 4 E-3
benzene	1,200	1 5 E-2	1,300	1 6 E-2	3,600	4 4 E-2	1,250	1 5 E-2
tetrachlororethene	20,146	2 5 E-1	9,474	1 2 E-1	77	9 4 E-4	14,810	1 8 E-1
arsenic	ND	NA	40	4 9 E-4	103	1 3 E-3	20	2 4 E-4
chromium	ND	NA	ND	NA	ND	NA	ND	NA

Notes
ND = Not Detected NA = Not Analyzed
(1) Exposure concentrations based on groundwater contaminant transport modeling (Appendix A)

(2) CDI = $\frac{[(\text{Exposure Conc}) \times (\text{total exposure time}) \times (\text{ingestion rate})]}{[(\text{body weight}) \times (\text{averaging time})]}$ (For values used in calculating CDI, see Table 3-5)

TABLE 3-4 (Cont.)

Calculated Exposure Concentrations and Intake Dose Rates

Media Air
Exposed Population Residential
Exposure Pathway Inhalation of chemicals that have volatilized from groundwater during showering
Exposure Time Future

Chemical Compound	EXPOSURE POINT							
	North of Gulf Pump Road				Riverdale		South of New Hwy 90	
	from INT-11 Area		from S1-13 Area		from INT-West Area		from INT-11 & S1-13 Areas	
	Exposure Concentration mg/m3 (3)	Chronic Daily Intake (CDI) (mg/kg-day) (2)	Exposure Concentration mg/m3	Chronic Daily Intake (CDI) (mg/kg-day)	Exposure Concentration mg/m3	Chronic Daily Intake (CDI) (mg/kg-day)	Exposure Concentration mg/m3	Chronic Daily Intake (CDI) (mg/kg-day)
vinyl chloride	60	4 4 E-2	73	5 3 E-2	160	1 2 E-1	66	4 9 E-2
methylene chloride	245	1 8 E-1	355	2 6 E-1	5	3 8 E-3	300	2 2 E-1
acetone	83	6 1 E-2	77	5 7 E-2	112	8 2 E-2	80	5 9 E-2
1,1-dichloroethene	15	1 1 E-2	10	7 0 E-3	1	9 9 E-4	12	9 1 E-3
1,1-dichloroethane	266	2 0 E-1	46	3 3 E-2	27	2 0 E-2	156	1 1 E-1
1,2-dichloroethene (total)	2,060	1 5 E+0	524	3.9 E-1	51	3 8 E-2	1,292	9 5 E-1
chloroform	6,213	4 6 E+0	959	7 0 E-1	2	1 3 E-3	3,586	2 6 E+0
1,2-dichloroethane	6,021	4 4 E+0	140	1 0 E-1	61	4 5 E-2	3,081	2 3 E+0
carbon tetrachloride	768	5 6 E-1	0 01	1 0 E-5	0 46	3 4 E-4	384	2 8 E-1
trichloroethene	48	3 5 E-2	140	1 0 E-1	5	3 7 E-3	93 69	6 9 E-2
1,1,2-trichloroethane	0 04	2 7 E-5	4	3 0 E-3	4	3 0 E-3	2	1 5 E-3
benzene	11	7 9 E-3	12	8 5 E-3	32	2 4 E-2	11	8 2 E-3
tetrachlororethene	136	1 0 E-1	64	4 7 E-2	1	3 8 E-4	100	7 4 E-2
arsenic	ND	NA	ND	NA	ND	NA	ND	NA
chromium	ND	NA	ND	NA	ND	NA	ND	NA

Notes

ND = Not Detected NA = Not Analyzed

(3) Exposure concentrations and CDI based on inhalation during showering with contaminated groundwater (Foster and Chrostowski, 1987) See Appendix B

TABLE 3-4 (Cont.)

Calculated Exposure Concentrations and Intake Dose Rates

Media: Surface Water
Exposure Time. Future
Exposed Population: Residential
Exposure Pathway: Ingestion of chemicals from surface water during swimming

Chemical Compound	EXPOSURE POINT					
	South Pond		East Pond		East Slough	
	Exposure Concentration ug/L (1)	Chronic Daily Intake (CDI) (mg/kg-day) (2)	Exposure Concentration ug/L	Chronic Daily Intake (CDI) (mg/kg-day)	Exposure Concentration ug/L	Chronic Daily Intake (CDI) (mg/kg-day)
vinyl chloride	383	2 5 E-5	366	2 4 E-5	1,022	6 7 E-5
methylene chloride	2,294	1 5 E-4	287	1 9 E-5	803	5 3 E-5
acetone	4,002	2 6 E-4	8,741	5 7 E-4	24,413	1 6 E-3
1,1-dichloroethene	60	3 9 E-6	14	8 9 E-7	38	2 5 E-6
1,1-dichloroethane	298	1 9 E-5	255	1 7 E-5	711	4 7 E-5
1,2-dichloroethene (total)	3,348	2 2 E-4	523	3 4 E-5	1,460	9 6 E-5
chloroform	6,901	4 5 E-4	967	6 3 E-5	2,701	1 8 E-4
1,2-dichloroethane	1,053	6 9 E-5	1,725	1 1 E-4	4,818	3 2 E-4
carbon tetrachloride	0 11	6 9 E-9	2	1 6 E-7	7	4 5 E-7
trichloroethene	998	6 5 E-5	3	2 1 E-7	9	5 7 E-7
1,1,2-trichloroethane	29	1 9 E-6	ND	NA	ND	NA
benzene	68	4 5 E-6	993	6 5 E-5	2,774	1 8 E-4
tetrachlororethene	499	3 3 E-5	ND	NA	ND	NA
arsenic	2	1 4 E-7	3	1 7 E-7	7	4 8 E-7
chromium	ND	NA	11	7 4 E-7	31	2 1 E-6

Notes

ND = Not Detected NA = Not Analyzed

(1) Exposure concentrations based on groundwater contaminant transport modeling and mixing with surface waters (Appendix A)

(2) $CDI = \frac{[(\text{Exposure Conc}) \times (\text{total exposure time}) \times (\text{ingestion rate})]}{[(\text{body weight}) \times (\text{averaging time})]}$

(For values used in calculating CDI, see Table 3-5)

TABLE 3-4 (Cont.)

Calculated Exposure Concentrations and Intake Dose Rates

Media Surface Water
Exposure Time: Future
Exposed Population: Residential
Exposure Pathway: Dermal contact with chemicals in surface water during swimming

Chemical Compound	EXPOSURE POINT					
	South Pond		East Pond		East Slough	
	Exposure Concentration ug/L (1)	Absorbed Dose (mg/kg-day) (2)	Exposure Concentration ug/L	Absorbed Dose (mg/kg-day)	Exposure Concentration ug/L	Absorbed Dose (mg/kg-day)
vinyl chloride	383	7 0 E-5	366	6 7 E-5	1,022	1 9 E-4
methylene chloride	2,294	3 3 E-4	287	4 1 E-5	803	1.1 E-4
acetone	4,002	4 6 E-3	8,741	1 0 E-2	24,413	2.8 E-2
1,1-dichloroethene	60	1 5 E-5	14	3 3 E-6	38	9.2 E-6
1,1-dichloroethane	298	3 5 E-4	255	3 0 E-4	711	8 2 E-4
1,2-dichloroethene (total)	3,348	3 6 E-3	523	5 7 E-4	1,460	1 6 E-3
chloroform	6,901	5 2 E-3	967	7 2 E-4	2,701	2.0 E-3
1,2-dichloroethane	1,053	5 2 E-4	1,725	8 5 E-4	4,818	2 4 E-3
carbon tetrachloride	0	5.7 E-9	2	1 3 E-7	7	3 8 E-7
trichloroethene	998	2 1 E-3	3	6 6 E-6	9	1 8 E-5
1,1,2-trichloroethane	29	7 3 E-5	ND	NA	ND	NA
benzene	68	7 4 E-5	993	1 1 E-3	2,774	3.0 E-3
tetrachlororethene	499	1 0 E-4	ND	NA	ND	NA
arsenic	2	1 7 E-8	3	2 1 E-8	7	5 9 E-8
chromium	0	0 0 E+0	11	9 0 E-8	31	2 5 E-7

Notes

ND = Not Detected NA = Not Analyzed

(1) Exposure concentrations based on groundwater contaminant transport modeling and mixing with surface waters (Appendix A)

(2) $CDI = \frac{[(\text{Exposure Conc}) \times (\text{total exposure time}) \times (\text{body surface area}) \times (\text{chemical permeability})]}{[(\text{body weight}) \times (\text{averaging time})]}$ (For values used in calculating CDI, see Table 3-5)

TABLE 3-4 (Cont.)

Calculated Exposure Concentrations and Intake Dose Rates

Media: Fish
Exposure Time: Future
Exposed Population: Residential
Exposure Pathway: Ingestion of contaminated fish from surface water ponds

Chemical Compound	EXPOSURE POINT					
	South Pond		East Pond		East Slough	
	Exposure Concentration ug/kg (1)	Chronic Daily Intake (CDI) (mg/kg-day) (2)	Exposure Concentration ug/kg	Chronic Daily Intake (CDI) (mg/kg-day)	Exposure Concentration ug/kg	Chronic Daily Intake (CDI) (mg/kg-day)
vinyl chloride	448	1 8 E-6	428	1 7 E-6	1,196	4 8 E-6
methylene chloride	11,468	4 6 E-5	1,437	5 7 E-6	4,015	1 6 E-5
acetone	4,002	1 6 E-5	8,741	3 5 E-5	24,413	9 7 E-5
1,1-dichloroethene	335	1 3 E-6	76	3 0 E-7	213	8 5 E-7
1,1-dichloroethane	298	1.2 E-6	255	1 0 E-6	711	2 8 E-6
1,2-dichloroethene (total)	5,357	2.1 E-5	836	3 3 E-6	2,336	9 3 E-6
chloroform	25,879	1 0 E-4	3,626	1 4 E-5	10,129	4 0 E-5
1,2-dichloroethane	1,263	5 0 E-6	2,070	8 2 E-6	5,782	2.3 E-5
carbon tetrachloride	2	8 0 E-9	47	1 9 E-7	132	5 2 E-7
trichloroethene	10,575	4 2 E-5	33	1 3 E-7	93	3 7 E-7
1,1,2-trichloroethane	146	5 8 E-7	ND	NA	ND	NA
benzene	356	1 4 E-6	5,164	2 1 E-5	14,425	5 7 E-5
tetrachlororethene	15,457	6 2 E-5	ND	NA	ND	NA
arsenic	93	3 7 E-7	115	4 6 E-7	321	1 3 E-6
chromium	ND	NA	2,248	8 9 E-6	6,278	2 5 E-5

Notes

ND = Not Detected NA = Not Analyzed

(1) Exposure conc in fish tissue (ug/kg) = water conc (ug/L) x bioconcentration factor (L/kg) (Table 3-2)

(2) CDI = $\frac{[(\text{exposure conc}) \times (\text{weight of contaminated fish consumed per year}) \times (\text{exposure time}}{[(\text{body weight}) \times (\text{averaging time})]}$ (For values used in calculating CDI, see Table 3-5)

As the DNAPL occurrence at the French Limited site is entirely below ground surface and cannot release chemicals directly to the atmosphere under normal conditions, the only potential direct atmospheric air exposure would be during excavation or drilling operations associated with remedial actions in DNAPL areas. As noted above, these activities are closely monitored and controlled so that the air exposure pathway was not considered for these specific exposure scenarios as part of the Risk Evaluation.

3.6.4 Estimation of Chemical Intake

The methodology for calculating chemical-specific intakes for the populations and exposure pathways selected for quantitative evaluation is described below.

Calculation of Groundwater and Surface Water Intakes

Potential future exposure to chemicals of concern in groundwater and surface water by a residential population and through the following routes was identified.

1. Ingestion of contaminated groundwater used as a drinking water supply.
2. Inhalation of chemicals that may volatilize from contaminated groundwater used as a drinking water supply, (e.g during showering).
3. Incidental ingestion of contaminated surface water while swimming.
4. Dermal contact with contaminated surface water while swimming.
5. Ingestion of fish caught from contaminated surface water ponds.

For calculating intakes for these exposure routes, the appropriate variables listed in the Human Health Evaluation Manual (EPA, 1989c) were generally used. The intake equations and variables values available for the five exposure pathways are included in Appendix B. The results of the exposure intake calculations are summarized in Table 3-4 and the values actually used in these calculations are summarized in Table 3-5.

For drinking water intakes, the standard ingestion volume of 2 liters per day was assumed for adults and 1 liter per day for children. The assumed exposure duration was 30 years (the 90th percentile for time spent at one residence) for an adult and 10 years for a child.

For inhalation of chemicals that may volatilize from contaminated groundwater supplies, an inhalation rate of 0.6 m^3 per hour and an exposure time of 12 minutes per day (90th percentile for showering) was assumed. The exposure frequency was assumed to be 365 days per year over a 30 year duration (the 90th percentile for time spent at one residence).

As recommended by the Human Health Evaluation Manual Supplemental Guidance "Standard Default Exposure Factors" (EPA, 1991a), the averaging time (AT) used for each exposure pathway was equal to the 30-year exposure duration for non-carcinogens and 70 years for carcinogens. In Table 3-4, Chronic Daily Intake (CDI) calculations are based on the 70 year averaging time. Adjustments are made for non-carcinogenic chemical intake in the Risk Characterization section (Section 5.0).

For incidental ingestion of surface water while swimming, an intake rate of 0 05 liters per hour and an exposure time of 2.6 hours per day was assumed. The exposure frequency was assumed to be 30 days per year over a 30 year duration These values reflect the relatively hot climate of the area and the fact that older adults are unlikely to swim in these ponds. For carcinogenic constituents the averaging time of 70 years was used.

For dermal contact with surface water while swimming, the dermal permeability values for specific chemicals listed in the Interim Guidance for Dermal Exposures (EPA, 1991d) were used. Exposure times and durations are the same as noted above for ingestion while swimming.

For ingestion of contaminated fish, an ingestion rate of 6.5 g/day (averaged over a year) was assumed. It was also assumed that 10% of the total fish consumed came from contaminated sources. The exposure duration was assumed to be over 30 years (the 90th percentile for time spent at one residence).

3.7 Combination of Chemical Intakes Across Pathways

The Reasonable Maximum Exposure (RME) at the site reflects the RME for a pathway as well as the RME across pathways. A given population may be exposed to a chemical from several exposure routes. For the various types of potential intake pathways, the highest RME intakes were combined to calculate an exposure that is a reasonable maximum across pathways. The combined risks associated with exposure through multiple pathways are addressed in the Risk Characterization in Section 5.0

TABLE 3-5

Summary of Variables used in Exposure Calculations

Exposure Pathway		Drinking Water (1)	Inhalation (2) While Showering
Intake Equation (mg/kg-day)		$\frac{CW \times IR \times EF \times ED}{BW \times AT}$	$\frac{CA \times IR \times ET \times EF \times ED}{BW \times AT}$
CW	Chemical concentration in water (mg/L)	(3)	--
CA	Contaminant concentration in air (mg/m3)	--	(4)
IR	Ingestion rate (L/day)	2	--
IR	Inhalation rate (m3/hour)	--	0.6
ET	Exposure time (hours/day)	--	0.2
EF	Exposure frequency (days/yr)	365	365
ED	Exposure duration (years)	30	30
BW	Body weight (kg)	70	70
AT	Averaging time (days) - carcinogens	25550 (70 yrs)	25550 (70 yrs)

Notes:

(1) See Appendix B-1 for more detailed summary of variables and sources of information
(2) See Appendix B-4 for more detailed summary of variables and sources of information
(3) See Table 3-4 for concentrations of specific chemicals for each exposure scenario
(4) See Table 3-4 for concentrations of specific chemicals for each exposure scenario

TABLE 3-5 (Cont.)

Summary of Variables used in Exposure Calculations

Exposure Pathway		Ingestion While Swimming (5)	Dermal Contact While Swimming (6)	Ingestion of Fish (7)
Intake Equation (mg/kg-day)		CW x CR x ET x EF x ED / BW x AT	CW x SA x PC x ET x EF x ED x CF / BW x AT	CF x IR x FI x EF X ED / BW x AT
CW	Chemical concentration in water (mg/L)	(8)	(9)	--
CR	Contact rate (L/hour)	0 05	--	--
CF	Chemical concentration in fish (mg/kg)	--	--	(11)
IR	Ingestion rate (kg/day) (averaged over year)	--	--	0 0065
SA	Skin surface area available for contact (cm2)	--	1940	--
PC	Chemical-specific dermal permeability constant (cm/hr)	--	(10)	--
FI	Fraction ingested from contaminated source (unitless)	--	--	0 1
ET	Exposure Time (hrs/day)	2 6	2 6	--
EF	Exposure frequency (days/yr)	30	30	365
ED	Exposure duration (years)	30	30	30
CF	Conversion factor for water (1 L/1000 cm3)	--	0 001	--
BW	Body weight (kg)	70	70	70
AT	Averaging time (days) - carcinogens	25550 (70 yrs)	25550 (70 yrs)	25550 (70 yrs)

Notes

(5) See Appendix B-2 for more detailed summary of variables and sources of information
(6) See Appendix B-3 for more detailed summary of variables and sources of information
(7) See Appendix B-5 for more detailed summary of variables and sources of information
(8) See Table 3-4 for concentrations of specific chemicals for each exposure scenario
(9) See Table 3-4 for concentrations of specific chemicals for each exposure scenario
(10) See Table 3-2 for specific chemicals
(11) See Table 3-4 for concentrations of specific chemicals for each exposure scenario

3.8 Evaluation of Uncertainty

The estimates of exposure described above are expected to be the maximum exposures that can be reasonably expected to occur. This is because the values of the most significant parameters that influence constituent transport in groundwater were selected very conservatively. Consequently, the calculated intake concentrations and the resulting risks are probably much higher than the average, but within the realm of reasonable assumptions.

In particular, the following parameters and assumptions support the RME concept.

Hydraulic Gradient For the drinking water scenarios, the value of hydraulic gradient was assumed to result from an aggressive groundwater dewatering operation that induces a groundwater flow gradient towards the receptor. The magnitude of the gradient is based on dewatering lowering the natural potentiometric head by about 30 feet. This gradient is many times greater than natural groundwater flow gradients but simulates the reasonable scenario of a gravel mining operation in the vicinity of a receptor population. Also this assumption is conservative in the sense that a gravel mining operation in this area would typically have a relatively short duration of 5 to 10 years, while groundwater flow under gradients imposed by these operations are assumed to be maintained for several times longer.

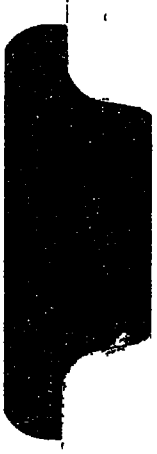
Natural Degradation Processes No natural degradation processes were assumed to occur that would reduce the modeled concentration of groundwater constituents at the receptor locations. This is the most conservative treatment of constituent fate and transport and tends to over-estimate receptor intake concentrations at any given time.

Transport Time Modeling indicates that constituents in groundwater reach receptor locations at different times depending on their adsorption characteristics. The intake concentrations used in the Risk Evaluation were based on the maximum concentration reaching the receptor, even though in some cases groundwater with this concentration does not reach the receptor location for tens to hundreds of years.

Intake Variables For the Riverdale drinking water scenarios, transport in the INT unit was modeled, as the potential DNAPL sources in the western site areas appear to be exclusively within this unit. Domestic wells providing the drinking water at the Riverdale receptor locations are assumed to tap only the INT interval containing the contaminated groundwater. In reality, the well would likely tap the entire alluvial sequence. The INT unit, because of its relatively low permeability, would provide only a small percentage of the total well yield This is, again, the most conservative treatment of constituent exposure and tends to over-estimate receptor intake concentrations.

3.9 Summary and Presentation of the Exposure Assessment Results

The results of the exposure assessment are summarized in Tables 3-4 and 3-5. These tables list the estimated chemical-specific intakes for each pathway to a residential population. This summary information only considers future potential exposures as current conditions do not provide any reasonable exposure routes and, hence, no risk. Detailed calculations supporting the exposure concentrations and intakes for each pathway are provided in Appendices A and B.



4.0 TOXICITY ASSESSMENT

This section provides basic toxicological information for the chemicals related to DNAPL-impacted areas at the French Limited site. The toxicity assessment seeks to develop the toxicity values used in characterizing the likelihood and/or severity of adverse human health effects associated with hypothetical chemical exposures. The results of the toxicity assessment are combined with the exposure assessment (Section 3.0) to characterize potential risks (Section 5.0). Definitions used in this section are included at the beginning of the report.

4.1 Background

EPA has performed the toxicity assessment step for numerous chemicals and has made available the resulting toxicity information and toxicity values, which have undergone extensive peer review. The latest information on toxicity of specific chemicals is accessible through a computerized database known as the Integrated Risk Information System (IRIS). IRIS is an EPA data base containing up-to-date health risk and EPA regulatory information for numerous chemicals. IRIS contains only toxicological reference data (RfDs, slope factors, unit risks, etc.) that have been verified by the relevant EPA Work Groups and, consequently, is the preferred source of toxicity information. Information in IRIS supersedes all other sources. Only when information was not available in IRIS were other sources consulted.

Toxicological data in IRIS were reviewed for all chemicals related to DNAPL-impacted areas at the site. These DNAPL-related chemicals were identified from chemical data from DNAPL, soil and groundwater samples collected at the site as reported in the *DNAPL Study Field Data Report* (AHA, November, 1993) as well as other groundwater monitoring data from the site. Maximum concentrations of chemicals detected in these media are summarized in Tables 2-2 and 2-3 in Section 2 of this report. Chemicals were included in these tables if they were detected in DNAPL, or if they were detected in soil or groundwater in the DNAPL-impacted areas of the site, outside the sheetpile cutoff wall. Although this approach may have resulted in retaining chemicals that are not related to DNAPL, it is conservative and reasonable given the relatively high detection limits for certain chemicals in the DNAPL analyses due to matrix interference and the limited information on background concentrations for metals[1].

[1] Arsenic was detected at concentrations of 20 µg/l in wells FLTG-4 and FLTG-13 which are thought to represent background conditions Maximum arsenic concentrations of 103, 10 and 40 µg/l were detected in the INT-West, S1-16 and S1-13 areas respectively (Table 2-3) Despite observed groundwater concentrations that are only slightly elevated above background values, arsenic is retained in the toxicity assessment because of the relative risks it contributes

The chemicals in Tables 2-2 and 2-3 were retained for toxicity assessment and for fate and transport assessment. Chemicals of Potential Concern were subsequently determined from this list following a concentration-toxicity screen, an evaluation of the carcinogenic weight-of-evidence and an evaluation of chemical fate and transport properties including mobility, solubility, persistence, bioaccumulation, etc.

The toxicity assessment for constituents related to DNAPL-impacted areas of the French Limited Site contains two components:

- Hazard Identification, which is the process of determining whether exposure to an identified chemical can cause an increase in the incidence of a particular adverse health effect (e.g., cancer, birth defect) and whether the adverse health effect is likely to occur in humans.

- Dose-Response Evaluation, which is the process of quantitatively evaluating the toxicity information and characterizing the relationship between the dose of the contaminant administered or received and the incidence of adverse health effects in the exposed population.

From this quantitative dose-response relationship, toxicity values (e.g., reference doses and slope factors) are derived that are used to estimate the incidence or potential for adverse effects as a function of human exposure to DNAPL-derived chemicals. The toxicity information regarding the development of the dose-response relationships and uncertainty factors which have been verified by EPA are included in the IRIS data base.

Several chemicals do not have verified toxicity values (slope factors and RfDs) in the IRIS data base, but are found in relatively high concentrations in DNAPL, soil and/or groundwater. These chemicals are vinyl chloride, 1,1-dichloroethane, trichloroethene, and naphthalene. The most recent "Health Effects Assessment Summary Tables" (HEAST) (EPA, 1993)[2] were reviewed to provide toxicity values necessary to evaluate, quantitatively, contribution to risk from these chemicals Toxicity values for carcinogenic effects for trichloroethene and naphthalene were not available from EPA (1993) because the weight-of-evidence classification for these chemicals is under review. However, slope factors previously published in HEAST (EPA, 1992 for naphthalene and EPA, 1990 for trichloroethene) were used for risk calculations. For the remaining chemicals, for which information was not available from EPA to evaluate quantitatively, the contributions to risk were identified and the results are discussed in Section 4.7.

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2 Toxicity information were obtained from EPA, 1993 "Health Effects Assessment Summary Tables", OERR PB93-921199. The quarterly Health Effects Assessment Summary Tables (HEAST) provide toxicity information in tabular format and includes chemicals that have not been verified by EPA for inclusion in IRIS

4.2 Hazard Identification

Hazard Identification involves characterizing the nature and strength of the evidence of causation. In hazard identification, chemical contaminants are separated into two categories of chemical toxicity: (1) chemicals which have noncarcinogenic or systemic effects; and (2) chemicals which exhibit the potential for carcinogenic effects in humans. Some chemicals produce effects in both categories. This is discussed further in Section 4.6.

4.2.1 Hazard Identification for Noncarcinogenic Effects

For chemicals that exhibit noncarcinogenic (e.g. systemic) effects, many authorities consider organisms to have repair and detoxification capabilities that must be exceeded by some critical concentration (threshold) before the health effect is manifested. This threshold value can be tolerated by the organism without an appreciable risk of adverse effects.

Noncarcinogenic or systemic effects may include effects on specific organs or systems, such as the kidney (nephrotoxicants), the liver (hepatotoxicants), the nervous system (neurotoxicants), the lungs (pulmonary toxicants), and reproductive toxicants. Health criteria for chemicals exhibiting noncarcinogenic effects for use in risk assessments were developed using USEPA oral reference doses (RfDs) developed by the RfD Work Group and reported in the IRIS database. The toxicity profiles for the identified chemicals detected in DNAPL-impacted areas are presented in IRIS and are summarized in Section 4.3. The toxicity profiles in IRIS describe the potential effects of acute and chronic exposure to these chemicals.

4.2.2 Hazard Identification for Carcinogenic Effects

For chemicals that exhibit carcinogenic effects, most authorities recognize that one or more molecular events can evoke changes in a single cell or a small number of cells that can lead to tumor formation. This is the non-threshold hypothesis for carcinogens in the absence of information concerning the mechanisms of action for the chemical.

EPA has developed a carcinogen-classification system (EPA, 1986a) using weight-of-evidence to classify the likelihood that a chemical is a human carcinogen. The available information from epidemiological evidence (human health studies) and evidence from controlled animal studies have been evaluated by EPA to determine the likelihood that the agent is a human carcinogen. The evidence is characterized separately for human studies and animal studies as sufficient, limited, inadequate, no data, or evidence of no effect. The characterizations of these two types of data are combined, and based on the extent to which the agent has been shown to be a carcinogen in experimental animals or humans, or both, the agent is given a provisional weight-of-evidence classification. EPA scientists then adjust the provisional classification upward or downward, based on other supporting evidence of carcinogenicity.

The EPA classification system for weight of evidence is shown in Table 4-1. This system is adapted from the approach taken by the International Agency for Research on Cancer (IARC 1982).

TABLE 4-1

EPA Weight-Of-Evidence Classification System For Carcinogenicity

Group	Description
A	Human carcinogen
B1	Probable human carcinogen - limited human data available
B2	Probable human carcinogen - sufficient evidence in animal and inadequate or no evidence in humans
C	Possible human carcinogen
D	Not classifiable as to human carcinogenicity
E	Evidence of non-carcinogenicity for humans

EPA weight-of-evidence carcinogenic classifications for chemicals detected in DNAPL-impacted areas of the French Limited site are indicated in Table 4-2.

TABLE 4-2

Toxicity Information for Chemicals Detected in DNAPL-Impacted Areas (1)

Chemical Name	CAS #	Oral RfD (mg/kg-day)	Inhalation RfC (mg/m3)	Carc. Class (2)	Oral Class	Oral Slope Factor (mg/kg-day) -1	Oral Unit Risk (per ug/L)	Inhal. Class	Inhalation Slope Factor (mg/kg-day) -1	Inhalation Unit Risk (per ug/m3)	Notes
Volatiles											
chloromethane	74-87-3			C	C	1 3 E-2	3.7 E-7	C	6.3 E-3	1.8 E-6	(3)
vinyl chloride	75-01-4			A	A	1 9 E+0	5.4 E-5	A	2 9 E-1	8.4 E-5	(4)
chloroethane	75-00-3		1 0 E+1								
methylene chloride	75-09-2	6.0 E-2	3 0 E+0 (4)	B2	B2	7 5 E-3	2.1 E-7	B2	1.6 E-3	4.7 E-7	
acetone	67-64-1	1.0 E-1		D							
1,1-dichloroethene	75-35-4	9 0 E-3		C	C	6 0 E-1	1 7 E-5	C	1.8 E-1	5.0 E-5	
1,1-dichloroethane	75-34-3	1.0 E-1	5 E-1 (4)	C							(4)
cis-1,2-dichloroethene	156-59-2	1.0 E-2		D							(4)
trans-1,2-dichloroethene	156-60-5	2.0 E-2									
chloroform	67-66-3	1 0 E-2		B2	B2	6 1 E-3	1 7 E-7	B2	8 1 E-2	2.3 E-5	
1,2-dichloroethane	107-06-2			B2	B2	9 1 E-2	2 6 E-6	B2	9 1 E-2	2.6 E-5	
2-butanone	78-93-3	6.0 E-1	1.0 E+1	D							
carbon tetrachloride	56-23-5	7.0 E-4		B2	B2	1.3 E-1	3 7 E-6	B2	5.3 E-2	1 5 E-5	
vinyl acetate	108-05-4	1 0 E+0 (4)	2 0 E-1								
trichloroethene	79-01-6				B2	1 1 E-2	3.1 E-7	B2	1 7 E-2	4.8 E-6	(5)
1,1,2-trichloroethane	79-00-5	4 0 E-3		C	C	5 7 E-2	1.6 E-6	C	5 6 E-2	1.6 E-5	
benzene	71-43-2			A	A	2.9 E-2	8.3 E-7	A	2.9 E-2	8.3 E-6	
4-methyl-2-pentanone	108-10-1										
tetrachlororethene (PCE)	127-18-4	1 0 E-2			B2	5 1 E-2	1.5 E-6	B2	3.3 E-3	9.4 E-7	(5)
1,1,2,2-tetrachloroethane	79-34-5			C	C	2.0 E-1	5.8 E-6	C	2.0 E-1	5.8 E-5	
toluene	108-88-3	2.0 E-1	4.0 E-1	D							
ethylbenzene	100-41-4	1 0 E-1	1.0 E+0	D							
xylene	1330-20-7	2.0 E+0		D							

(1) All toxicological data obtained from IRIS database (as of April, 1994) unless otherwise noted
(2) For Carcinogen Class explanation see Table 4-1
(3) Obtained from U S EPA, "Health Effects Assessment Summary Tables," Supplement No 1 to March 1993 Annual Update, OERR PB93-921101 July, 1993
(4) Obtained from U S EPA, "Health Effects Assessment Summary Tables," Annual, FY-1993, OERR PB93-921199 March, 1993
(5) Obtained from U S EPA, "Health Effects Assessment Summary Tables," Fourth Quarter, FY-1990, OSWER PB90-921104

TABLE 4-2 (Cont.)

Toxicity Information for Chemicals Detected in DNAPL-Impacted Areas (1)

Chemical Name	CAS #	Oral RfD (mg/kg-day)	Inhalation RfC (mg/m3)	Carc Class (2)	Oral Class	Oral Slope Factor (mg/kg-day) -1	Oral Unit Risk (per ug/L)	Inhal Class	Inhalation Slope Factor (mg/kg-day) -1	Inhalation Unit Risk (per ug/m3)	Notes
Semi-Volatiles											
phenol	108-95-2	6 0 E-1		D							
2-methylphenol	95-48-7	5 0 E-2		C							
4-methylphenol	106-44-5	5.0 E-3		C							(4)
hexachloroethane	67-72-1	1.0 E-3		C	C	1.4 E-2	4.0 E-7	C	1.4 E-2	4 0 E-6	
2-4-dimethylphenol	105-67-9	2 0 E-2									
1,2,4-trichlorobenzene	120-82-1	1 0 E-2		D							
naphthalene	91-20-3	4 0 E-2		D							(6)
hexachlorobutadiene	87-68-3	2 0 E-4 (3)		C	C	7 7 E-2	2 2 E-6	C	7 7 E-2	2 2 E-5	
2-methylnaphthalene	91-57-6										
acenaphthylene	208-96-8			D							(7)
acenaphthene	83-32-9	6 0 E-2									
dibenzofuran	132-64-9			D							(7)
fluorene	86-73-7	4 0 E-2		D							
hexachlorobenzene	118-74-1	8 0 E-4		B2	B2	1 6 E+0	4 6 E-5	B2	1 6 E+0	4 6 E-4	
phenanthrene	85-01-8			D							(7)
anthracene	120-12-7	3 0 E-1		D							
fluoranthene	206-44-0	4.0 E-2		D							
pyrene	129-00-0	3 0 E-2		D							
benzo(A)anthracene	56-55-3			B2							
bis(2-ethylhexyl)phthalate	117-81-7	2 0 E-2		B2	B2	1 4 E-2	4 0 E-7				
chrysene	218-01-9			B2							(7)
benzo(B)fluoranthene	205-99-2			B2							
benzo(A)pyrene	50-32-8			B2	B2	7 4 E+0	2 1 E-4				
indeno(1,2,3-CD)pyrene	193-39-5			B2							
dibenzo(A,H)anthracene	53-70-3			B2							
benzo(GHI)perylene	191-24-2			D							

(1) All toxicological data obtained from IRIS database (as of April, 1994) unless otherwise noted
(2) For Carcinogen Class explanation see Table 4-1
(4) Obtained from U S EPA, "Health Effects Assessment Summary Tables," Annual, FY-1993, OERR PB93-921199 March, 1993
(6) Obtained from U S EPA, "Health Effects Assessment Summary Tables," Annual, FY-1992, OERR 9200 6-303(92)
(7) Available data inadequate for quantitative risk assessment (HEAST, 1993)

TABLE 4-2 (Cont.)

Toxicity Information for Chemicals Detected in DNAPL-Impacted Areas (1)

Chemical Name	CAS #	Oral RfD (mg/kg-day)	Inhalation RfC (mg/m3)	Carc Class (2)	Oral Class	Oral Slope Factor (mg/kg-day) -1	Oral Unit Risk (per ug/L)	Inhal. Class	Inhalation Slope Factor (mg/kg-day) -1	Inhalation Unit Risk (per ug/m3)	Notes
Pesticides											
alpha-BHC	319-84-6			B2	B2	6 3 E+0	1 8 E-4	B2	6 3 E+0	1 8 E-3	
beta-BHC	319-85-7			C	C	1 8 E+0	5 3 E-5	C	1 8 E+0	5 3 E-4	
delta-BHC	319-86-8			D							(7)
gamma-BHC (Lindane)	319-89-9	3 0 E-4									
aldrin	309-00-2	3 0 E-5		B2	B2	1.7 E+1	4 9 E-4	B2	1 7 E+1	4 9 E-3	
4,4 DDE	72-55-9			B2	B2	3 4 E-1	9 7 E-6				
endrin	72-20-8	3.0 E-4		D							
endrin aldehyde	7421-93-4										
heptachlor	76-44-8	5 0 E-4		B2	B2	4 6 E+0	1 3 E-4	B2	4 6 E+0	1 3 E-3	
PCB	1336-36-3			B2	B2	7.7 E+0	2.2 E-4				
Metals											
arsenic	7440-38-2	3 0 E-4		A	A	1 8 E+0	5 0 E-5	A	5 0 E+1 (4)	4 3 E-3	
chromium (III)	8540-29-9	5.0 E-3							4 2 E+1	1.2 E-2	(8)
copper	7440-50-8										(9)
zinc	7440-66-6	3 0 E-1		D							

(1) All toxicological data obtained from IRIS database (as of April, 1994) unless otherwise noted
(2) For Carcinogen Class explanation see Table 4-1
(4) Obtained from U S EPA, "Health Effects Assessment Summary Tables," Annual, FY-1993, OERR PB93-921199 March, 1993
(7) Available data inadequate for quantitative risk assessment (HEAST, 1993)
(8) Values are for hexavalent chromium
(9) No value for chronic RfD Current drinking water standard for copper is 1 3 mg/L

4.3 Dose-Response Evaluation for Noncarcinogenic Effects

A reference dose, or RfD, is the critical toxicity value used in evaluating the dose-response relationship for noncarcinogenic effects resulting from exposures at the site. Additionally, One-day or Ten-day Health Advisories (HAs) may be used to evaluate short-term oral exposures. The methods used for developing RfDs and HAs are described below. Various types of RfDs are available depending on the exposure route (oral or inhalation), the critical effect (developmental or other), and the length of exposure being evaluated (chronic, subchronic, or single event).

A chronic RfD is defined as an estimate (with uncertainty spanning perhaps an order of magnitude or greater) of a daily exposure level for the human population, including sensitive subpopulations, that is likely to be without an appreciable risk of deleterious effects during a lifetime. Chronic RfDs are specifically developed to be protective for long-term exposure to a compound. The RfD is generally expressed in units of milligrams per kilogram of body weight per day (mg/kg/day).

Subchronic RfDs (RfD_Ss), are useful for characterizing potential noncarcinogenic effects associated with shorter-term exposures. Chronic RfDs were used in this assessment since they provide more conservative results.

4.3.1 Derivation of an Oral RfD (RfD_O)

Oral RfDs are generally derived from epidemiological (human health effects) studies or controlled animal studies. Uncertainty factors and modifying factors are used to derive RfDs from the No Observed Adverse Effects Level (NOAEL) or the Lowest Observed Adverse Effect Level (LOAEL) in animal studies. The larger these factors are, the more uncertainty is associated with the RfD.

The RfD is derived from the NOAEL (or LOAEL) for the critical toxic effect by consistent application of uncertainty factors (UFs) and a modifying factor (MF). The uncertainty factors generally consist of multiples of 10 (although values less than 10 are sometimes used), with each factor representing a specific area of uncertainty inherent in the extrapolation from the available data. The bases for application of difference uncertainty factors are explained below.

- A UF of 10 is used to account for variation in the general population and is intended to protect sensitive subpopulations (e.g., elderly, children)

- A UF of 10 is used when extrapolating from animals to humans. This factor is intended to account for the interspecies variability between humans and other mammals.

- A UF of 10 is used when a NOAEL derived from a subchronic instead of a chronic study is used as the basis for a chronic RfD.

- A UF of 10 is used when a LOAEL is used instead of a NOAEL. This factor is intended to account for the uncertainty associated with extrapolating from LOAELs to NOAELs.

In addition to the UFs listed above, a modifying factor (MF) is applied.

- An MF ranging from >0 to 10 is included to reflect a qualitative professional assessment of additional uncertainties, in the critical study and in the entire data base, for the chemical not explicitly addressed by the preceding uncertainty factors. The default value for the MF is 1.

To calculate the RfD, the appropriate NOAEL (or the LOAEL if a suitable NOAEL is not available) is divided by the product of all of the applicable uncertainty factors and the modifying factor as follows:.

$$RfD = NOAEL \text{ or } LOAEL/(UF_1 \times UF_2 \times MF)$$

Oral RfDs typically are expressed as one significant figure in units of mg/kg-day. These concepts are shown graphically in EPA (1989c). To date, most RfDs developed by EPA are based on administered doses, not absorbed doses.

The toxicity information used in developing RfDs for chemicals detected in DNAPL-impacted areas of the French Limited site are included in the toxicity profiles provided in IRIS. Oral reference doses for these chemicals are listed in Table 4-2. The primary source of the RfD values in Table 4-2 was the IRIS database. If values were not available in IRIS, then the most recent HEAST values (EPA, 1993) were used, as noted in Table 4-2. For naphthalene, the RfD value from the 1992 HEAST manual was used, as noted in Table 4-2, as there was no reported RfD value in the IRIS or the 1993 HEAST.

Results of chemical analyses of subsurface media at the site report both trans-1,2-dichloroethene and cis-1,2-dichloroethene as total 1,2-dichloroethene. The oral RfD for trans-1,2-dichloroethene from IRIS is used in this assessment for 1,2-dichloroethene because the RfD for cis-1,2-dichloroethene is under review by EPA (HEAST, 1993) and its current value is lower than that of trans-1,2-dichloroethene.

4.3.2 Derivation of an Inhalation RfD

The methods EPA uses in the derivation of inhalation RfDs are similar in concept to those used for oral RfDs. However, the actual analysis of inhalation exposures is more complex than oral exposures due to (1) the dynamics of the respiratory system and its diversity across species and (2) differences in the physicochemical properties of contaminants.

Although in theory the identification of the critical study and the determination of the NOAEL is similar for oral and inhalation exposures, several important differences should be noted. In selecting the most appropriate study, EPA considers differences in respiratory anatomy and physiology, as well as differences in the physicochemical characteristics of the contaminant. Differences in respiratory anatomy and physiology may affect the pattern of contaminant deposition in the respiratory tract, and the clearance and redistribution of the agent. Consequently, two different species may not receive the same dose of the contaminant at the same locations within the respiratory tract even though both species were exposed to the same particle or gas concentration. Differences in the physicochemical characteristics of the contaminants, such as the size and shape of a particle, also influence deposition, clearance, and redistribution.

In inhalation exposures, the target tissue may be a portion of the respiratory tract or, if the contaminant can be absorbed and distributed through the body, some extra-respiratory organ. The toxic health effect observed may be more directly related to the pattern of deposition than to the exposure concentration, because the pattern of deposition may influence concentrations at the alveolar exchange boundary or different tissues of the lung. Consequently, EPA considers the deposition, clearance mechanisms, and the physicochemical properties of the inhaled agent in determining the effective dose delivered to the target organ.

The inhalation RfD is derived from the NOAEL by applying uncertainty factors (UFs) similar to those listed above for oral RfDs. The UF of 10 is used when extrapolating from animals to humans, in addition to calculation of the human equivalent dose, to account for interspecific variability in sensitivity to the toxicant. The resulting RfD value for inhalation exposure is, generally, reported as a concentration in air or Reference Concentration (RfC) (in mg/m^3 for continuous, 24 hour/day exposure) although it may also be reported as a corresponding inhaled intake (in mg/kg day) A human body weight of 70 kg and an inhalation rate of 20 m^3/day are used to convert between an inhaled intake expressed in units of mg/kg-day and a concentration in air or RfC expressed in mg/m^3.

The toxicity information used in developing inhalation RfCs for chemicals detected in DNAPL-impacted areas of the site are included in the toxicity profiles provided in IRIS. Inhalation reference concentrations for DNAPL-related chemicals from IRIS are listed in Table 4-2. The source of the inhalation RfCs in Table 4-2 is the IRIS database unless otherwise noted.

4.3.3 One-Day and Ten-Day Health Advisories

Reference values that may be useful for evaluating potential adverse effects associated with oral exposures of shorter duration have been developed by the Office of Drinking Water. These values are known as One-day and Ten-day Health Advisories, which are issued as nonregulatory guidance. Health Advisory values are concentrations of contaminants in drinking water at which adverse health effects would not be expected to occur for an exposure of the specified duration. The Health Advisory values are based on data describing noncarcinogenic effects and are derived by dividing a NOAEL or LOAEL by the appropriate uncertainty and modifying factors. They are based on the assumption that a 10-kg child drinks one liter of water per day. A margin of safety is included to protect sensitive members of the population. One-day and Ten-day Health Advisories do not consider any carcinogenic risk associated with the exposure even if the compound is a potential carcinogen.

The One-day and Ten-day Health Advisory values for DNAPL-related chemicals at the site are summarized in Table 4-3 along with pertinent environmental and drinking water criteria.

4.4 Dose-Response Evaluation for Carcinogenic Effects

While the carcinogenic hazard identification generally relies on a weight-of-evidence evaluation of all available information from epidemiological evidence (human health studies) and results of controlled animal studies to determine the likelihood that the agent is a human carcinogen, the dose-response relationships for those chemicals exhibiting carcinogenic effects are generally derived from experimental studies on animals. Current EPA guidelines recommend the use of a linearized multistage model, when appropriate, for extrapolating from the high exposure levels used in animal experiments to low exposure levels typical of environmental exposures (EPA, 1989c). The model assumes that there is no threshold for carcinogenesis. The toxicity value used to describe the dose-response relationship for carcinogenic chemicals is called the slope factor.

TABLE 4-3

Health Advisories, Environmental and Drinking Water Criteria

Chemical Name	1-Day HA (mg/L) (1)	10-Day HA (mg/L) (1)	Water and Fish (ug/L) 2	Aquatic Acute (ug/L) 3	Aquatic Chronic (ug/L) 3	MCLG (mg/L) (4)	MCL (mg/L) (5)
Volatiles							
chloromethane							
vinyl chloride							
chloroethane				860,000	230,000		
methylene chloride	13.3	1.5	0 19	11,000		0	0.005
acetone							
1,1-dichloroethene			0 033	11,600		0.007	0 007
1,1-dichloroethane							
cis-1,2-dichloroethene			0 033	11,600		0 07	0.07
trans-1,2-dichloroethene				11,600		0.1	0 1
chloroform			0 19	28,900	1,240		0 1
1,2-dichloroethane			0 94	18,000	20,000	0	0.005
2-butanone							
carbon tetrachloride	4	0 16	0 4	35,200		0	0 005
vinyl acetate							
trichloroethene			2 7	45,000	21,900	0	0 005
1,1,2-trichloroethane	0 6	0.4	0 6	18,000	9,400	0.003	0.005
benzene		0 235	0 66	5,300		0	0 005
4-methyl-2-pentanone							
tetrachlororethene		2					
1,1,2,2-tetrachloroethane			0.17	9,320	2,400		
toluene	20	3	14,300	17,500		1	1
ethylbenzene	32	3 2	1,400	32,000		0 7	0.7
xylene						10	10

(1) Drinking Water Health Advisory
(2) Recommended water quality criteria when exposure is via ingestion of water and aquatic organisms
Usually associated with upper-bound excess lifetime risk of 1 0E-6 EPA, Criteria and Standards Division, OWRS
(3) Recommended water quality criteria for aquatic organisms EPA, Criteria and Standards Division, OWRS
(4) Maximum Contaminant Level Goal for drinking water EPA, Health and Ecological Criteria Division, OST
(5) Maximum Contaminant Level Criteria for drinking water EPA, Drinking Water Standards Division, OGWDW

TABLE 4-3 (Cont.)

Health Advisories, Environmental and Drinking Water Criteria

Chemical Name	1-Day HA (mg/L)	10-Day HA (mg/L)	Water and Fish (ug/L)	Aquatic Acute (ug/L)	Aquatic Chronic (ug/L)	MCLG (mg/L)	MCL (mg/L)
Semi-Volatiles							
phenol			3,500	10,200	2,560		
2-methylphenol							
4-methylphenol							
hexachloroethane			1 9	980	540		
2-4-dimethylphenol				2,120			
1,2,4-trichlorobenzene				250	50	0 009	0 009
naphthalene				2,300	620		
hexachlorobutadiene		0 3	0 45	90	9		
2-methylnaphthalene							
acenaphthylene			0 0028				
acenaphthene							
dibenzofuran							
fluorene			0 0028				
hexachlorobenzene			0 00072	0 6	3 68	0	0 001
phenanthrene			0 0028	30	6 3		
anthracene			0 0028				
fluoranthene			42	3,980			
pyrene			0.0028				
benzo(A)anthracene			0 0028			0	0 0002
bis(2-ethylhexyl)phthalate			15,000	400	360	0	0 004
chrysene			0.0028			0	0 0002
benzo(B)fluoranthene			0 0028			0	0 0002
benzo(A)pyrene			0 0028			0	0 0002
indeno(1,2,3-CD)pyrene			0 0028			0	0 0002
dibenzo(A,H)anthracene			0 0028			0	0 0002
benzo(GHI)perylene			0 0028				

(1) Drinking Water Health Advisory
(2) Recommended water quality criteria when exposure is via ingestion of water and aquatic organisms
Usually associated with upper-bound excess lifetime risk of 1 0E-6 EPA, Criteria and Standards Division, OWRS
(3) Recommended water quality criteria for aquatic organisms EPA, Criteria and Standards Division, OWRS
(4) Maximum Contaminant Level Goal for drinking water EPA, Health and Ecological Criteria Division, OST
(5) Maximum Contaminant Level Criteria for drinking water EPA, Drinking Water Standards Division OGWDW

TABLE 4-3 (Cont.)

Health Advisories, Environmental and Drinking Water Criteria

Chemical Name	1-Day HA (mg/L)	10-Day HA (mg/L)	Water and Fish (ug/L)	Aquatic Acute (ug/L)	Aquatic Chronic (ug/L)	MCLG (mg/L)	MCL (mg/L)
Pesticides							
alpha-BHC			0 0092	100			
beta-BHC							
delta-BHC							
gamma-BHC (Lindane)	1	1 2					
aldrin							
4,4 DDE				1,050			
endrin			1				
endrin aldehyde							
heptachlor		0 01	0 00028	0 52	0 0038	0	0 0004
PCB			0 000079	2	0 014	0	0 0005
Metals							
arsenic			0 0022	360	190	0 05	0 05
chromium (6)	1 4	1 4	50	16	11	0 1	0 1
copper							1 3
zinc				120	110		5

(1) Drinking Water Health Advisory
(2) Recommended water quality criteria when exposure is via ingestion of water and aquatic organisms
Usually associated with upper bound excess lifetime risk of 1 0E-6 EPA, Criteria and Standards Division, OWRS
(3) Recommended water quality criteria for aquatic organisms EPA, Criteria and Standards Division, OWRS
(4) Maximum Contaminant Level Goal for drinking water EPA, Health and Ecological Criteria Division, OST
(5) Maximum Contaminant Level Criteria for drinking water EPA, Drinking Water Standards Division, OGWDW
(6) All Health Advisory values for chromium are based on total chromium (III and VI)

4.4.1 Slope Factors

Based on the determination of the Hazard Evaluation that the chemical is a known or probable human carcinogen, a toxicity value is determined that defines quantitatively the relationship between dose and response (i.e., the slope factor). Slope factors are typically calculated for potential carcinogens in classes A, B1, and B2 (Table 4-1). Quantitative estimation of slope factors for the chemicals in class C proceeds on a case-by-case basis.

EPA's Carcinogen Assessment Group (CAG) has developed slope factors (i.e. dose-response values) for estimating excess lifetime cancer risks associated with various levels of lifetime exposure to potential human carcinogens. The slope factor is a plausible upper bound estimate of the probability of a carcinogenic response per unit intake of a chemical over a lifetime. The upper 95th percentile confidence limit slope of the curve from the linearized multistage model of animal data is subjected to an interspecies scaling factor to conservatively derive the slope factor for humans. Slope factors are expressed as the inverse of milligrams of chemical per kilogram of body weight per day $(mg/kg\text{-}day)^{-1}$. In addition, there are varying degrees of confidence in the weight of evidence for carcinogenicity of a given chemical as described previously in Section 4.2.2.

Slope factors for use in risk assessments are reported in the IRIS database. The slope factor is a number which, when multiplied by the lifetime average daily dose of a potential carcinogen, yields the upper bound lifetime excess cancer risk associated with exposure at that dose. Excess lifetime cancer risks are generally expressed, in scientific notation, in the form of probabilities. For example, an excess lifetime cancer risk of 10^{-6} (one in a million), represents the probability that an individual will develop cancer as a result of exposure to a carcinogenic chemical over a 70-year lifetime under specified exposure conditions.

Slope factors are accompanied by the weight-of-evidence classification to indicate the strength of the evidence that the agent is a human carcinogen. The slope factor from the linearized multistage model is also known as the q_1. That is:

Slope factor (q_1) = risk per unit dose
= risk per mg/kg-day

Where data permit, slope factors listed in IRIS are based on absorbed doses, although to date many of them have been based on administered doses.

4.4.2 Toxicity Values for Carcinogenic Effects

Toxicity values for carcinogenic effects can be expressed in several ways. They can be expressed by the slope factor in $(mg/kg\text{-}day)^{-1}$. Alternatively, they can be expressed in terms of risk per unit concentration of the substance in the medium where human contact occurs. These measures, called unit risks, are calculated by dividing the slope factor by 70 kg (the average weight of an adult) and multiplying by the inhalation rate (20 m^3/day) for inhalation risk assessment or the water consumption rate (2 liters/day) for oral ingestion risk assessment. These unit risk values are equivalent to the inhalation risk associated with a unit concentration in air and the oral ingestion risk associated with a unit concentration in water. Where an absorption fraction less than 1.0 has been applied in deriving the slope factor, an additional conversion factor is necessary in the calculation of unit risk, so that the unit risk will be on an administered dose basis.

The standardized duration assumption for unit risks is understood to be continuous lifetime exposure. Hence, when there is no absorption conversion required:

inhalation unit risk = risk per ug/m^3
= slope factor x 1/70 kg x 20 m^3/day x 10^{3}

oral unit risk = risk per ug/L
= slope factor x 1/70 kg x 2L/day x 10^{-3}

The multiplication by 10^{-3} is necessary to convert from mg (the slope factor, or q_1, is given in $(mg/kg\text{-}day)^{-1}$) to ug (the unit risk is given in $(ug/m^3)^{-1}$ or $(ug/L)^{-1}$).

Inhalation and oral unit risk factors for chemicals detected in DNAPL-impacted areas of the site are reported in Table 4-2. The source of these values is the IRIS database unless otherwise noted on Table 4-2. A notation of the EPA weight-of-evidence classification has also been included with the unit risk factors. Several chemicals in Table 4-2 have risk factors obtained from HEAST as there is no value available in IRIS. These toxicity values are under review by EPA and have not been validated by EPA's Carcinogen Risk Assessment Verification Endeavor (CRAVE) Work Group. Slope factors verified by CRAVE have undergone extensive peer review and represent an Agency consensus. CRAVE-verified review summaries (similar to RfD Work group summaries) are entered into the IRIS data base.

4.5 Dermal Exposure

No RfDs or slope factors are available for the dermal route of exposure. In some cases, however, noncarcinogenic or carcinogenic risks associated with dermal exposure can be evaluated using an oral RfD or oral slope factor, respectively. In brief, exposures via the dermal route generally are calculated and expressed as absorbed doses. These absorbed doses are compared to an oral toxicity value that has been adjusted, if necessary, so that it too is expressed as an absorbed dose.

It is inappropriate to use the oral slope factor to evaluate the risks associated with dermal exposure to carcinogens such as benz(a)pyrene, which cause skin cancer through a direct action at the point of application. These types of skin carcinogens and other locally active compounds must be evaluated separately from the above method. Generally, only a qualitative assessment of risks from dermal exposure to these chemicals is possible. This does not apply to carcinogens such as arsenic, which are believed to cause skin cancer through a systemic rather than local action.

4.6 Summarization of Toxicity Information and Identification of Potential Contaminants of Concern

Summaries of the available toxicity values for all chemicals detected in DNAPL-impacted areas of the site are provided in Tables 4-2 and 4-3. EPA's weight-of-evidence classification is included on Table 4-2.

Maximum concentrations of these chemicals in various media at the site are summarized in Table 2-2. Maximum concentrations of these chemicals in groundwater in the four source areas are summarized in Table 2-3. Some of these chemicals are present in soil and groundwater at very low concentrations that are not expected to be toxic. Others are found only in the DNAPL, or DNAPL-impacted soil, and not found in groundwater. These chemicals would only pose a risk upon exposure during excavation or drilling activities. As noted in Section 3.5.1, direct exposure to DNAPL and DNAPL-impacted soils via dermal contact, incidental ingestion or inhalation of volatilized compounds is controlled or prevented by local conditions. These are therefore not considered realistic potential exposure pathways in this Risk Evaluation.

Guidance from EPA (1989c) was followed to reduce the list of chemicals so that the Risk Evaluation focuses on those chemicals that are expected to be the significant contributors to the potential health risks. The reduction in the list of chemicals, and the resulting generation of the list of chemicals of potential concern was accomplished by (1) performing a concentration/toxicity screen and (2) considering fate and transport characteristics of DNAPL-related chemicals.

4.6.1 Concentration/Toxicity Screening

For noncarcinogenic risk screening, the maximum concentration of chemicals in groundwater was multiplied by an assumed consumption of 2 L of water per day per 70 kg adult to obtain a dose rate. This dose rate was divided by the chronic oral RfD to obtain the Noncancer Hazard Quotient as shown in Table 4-4 All chemicals with a Noncancer Hazard Quotient equal to or greater than 1.0 were retained based on the concentration/toxicity screen. The mobility and concentration of these chemicals in groundwater at the French Limited site were then evaluated as a second screening method as described in Section 4.6.2. Chemicals passing both screenings were retained as potential chemicals of concern for this Risk Evaluation (Table 4-5).

For potential carcinogens, the maximum concentration in groundwater was multiplied by the oral unit risk to obtain the Cancer Risk as shown in Table 4-4. The percent contribution to total cancer risk was calculated for each chemical, and the chemicals ranked from highest to lowest as shown in Table 4-5. EPA (1989c) suggests that chemicals individually contributing less than 1 percent of the total risk score may be deleted from further evaluation as chemicals of potential concern. However, in this screen, chemicals individually contributing more than 0.1 percent of the total risk score were retained. In addition, benzene was retained, even though it contributed slightly less than the 0.1% of the total carcinogenic risk, because of the high concentrations, prevalence and mobility of this chemical in groundwater at the site.

The eleven potential carcinogens which were retained for fate and transport screening accounted for 99.78% of the total cancer risk based on maximum concentrations measured in groundwater (Table 4-5). As indicated above, chemicals that passed the toxicity screening were evaluated for fate and transport characteristics as a second screening method (Section 4.6.2). Chemicals passing both screenings were retained as potential chemicals of concern for this Risk Evaluation (Table 4-5).

Even though the standard toxicity screening criteria are not met, it may be reasonable to retain some semivolatile compounds on the basis of the implications of the future selection of remediation alternatives. However, the concentrations of semi-volatile compounds occurring in groundwater outside the floodwall at the French Limited site is generally non-detectable or very low (Table 4-4). It is unlikely that these low concentration values would influence the selection of a remedial alternative based on treatment considerations.

TABLE 4-4

Concentration/Toxicity Screening

Chemical Name	Max. GW Conc. (ug/L) (1)	Dose Rate (mg/kg/day) (2)	Oral RfD (mg/kg/day) (3)	Noncancer Hazard Quotient (4)	Oral Unit Risk (per ug/L) (3)	Cancer Risk (5)	1-Day HA (mg/L) (6)	10-Day HA (mg/L) (6)
Volatiles								
chloromethane	12	3 4 E-4			3 7 E-7	4.4 E-6		
vinyl chloride	16,000	4.6 E-1			5 4 E-5	8.6 E-1		
chloroethane	15,000	4 3 E-1						
methylene chloride	43,581	1 2 E+0	6 0 E-2	2 1 E+1	2.1 E-7	9 2 E-3	13.3	1 5
acetone	110,000	3 1 E+0	1 0 E-1	3.1 E+1				
1,1-dichloroethene	1,800	5 1 E-2	9 0 E-3	5 7 E+0	1.7 E-5	3 1 E-2		
1,1-dichloroethane	33,000	9 4 E-1	1.0 E-1	9.4 E+0				
cis-1,2-dichloroethene	250,000	7.1 E+0	1 0 E-2	7.1 E+2				
trans-1,2-dichloroethene	250,000	7 1 E+0	2 0 E-2	3.6 E+2				
chloroform	850,000	2 4 E+1	1 0 E-2	2 4 E+3	1.7 E-7	1 4 E-1		
1,2-dichloroethane	860,000	2 5 E+1			2 6 E-6	2.2 E+0		
2-butanone	4,400	1.3 E-1	6 0 E-1	2.1 E-1				
carbon tetrachloride	110,000	3 1 E+0	7.0 E-4	4.5 E+3	3 7 E-6	4.1 E-1	4	0 16
vinyl acetate	1,500	4.3 E-2	1.0 E+0	4.3 E-2				
trichloroethene	18,957	5.4 E-1			3 1 E-7	6 0 E-3		
1,1,2-trichloroethane	556	1 6 E-2	4 0 E-3	4 0 E+0	1.6 E-6	8 9 E-4	0.6	0.4
benzene	3,800	1 1 E-1			8 3 E-7	3.2 E-3		0.235
4-methyl-2-pentanone	2,100	6 0 E-2						
tetrachlororethene	20,146	5 8 E-1	1 0 E-2	5 8 E+1	1 5 E-6	2 9 E-2		2
1,1,2,2-tetrachloroethane	674	1 9 E-2			5 8 E-6	3 9 E-3		
toluene	1,200	3.4 E-2	2 0 E-1	1 7 E-1			20	3
ethylbenzene	690	2 0 E-2	1 0 E-1	2 0 E-1			32	3 2
xylene	1,533	4 4 E-2	2 0 E+0	2 2 E-2				

(1) See Table 2-2
(2) Dose Rate assumes a consumption of 2 L of water per day per 70 kg adult
(3) See Table 4-2
(4) Noncancer Hazard Quotient = exposure level/reference dose
(5) Cancer Risk = concentration x unit risk
(6) HA = Health Advisory

TABLE 4-4 (Cont.)

Concentration/Toxicity Screening

Chemical Name	Max GW Conc (ug/L) (1)	Dose Rate (mg/kg/day) (2)	Oral RfD (mg/kg/day) (3)	Noncancer Hazard Quotient (4)	Oral Unit Risk (per ug/L) (3)	Cancer Risk (5)	1-Day HA (mg/L) (6)	10-Day HA (mg/L) (6)
Semi-Volatiles								
phenol	1,200	3 4 E-2	6 0 E-1	5 7 E-2				
2-methylphenol	8	2 3 E-4	5 0 E-2	4 6 E-3				
4-methylphenol	17	4 9 E-4	5 0 E-3	9.7 E-2				
hexachloroethane	140	4 0 E-3	1 0 E-3	4 0 E+0	4 0 E-7	5 6 E-5		
2-4-dimethylphenol	ND		2 0 E-2	NA				
1,2,4-trichlorobenzene	7	2 0 E-4	1.0 E-2	2.0 E-2				
naphthalene	200	5 7 E-3	4 0 E-2	1 4 E-1				
hexachlorobutadiene	ND		2.0 E-4	NA	2 2 E-6	NA		0 3
2-methylnaphthalene	14	4 0 E-4						
acenaphthylene	ND							
acenaphthene	18	5 1 E-4	6 0 E-2	8 6 E-3				
dibenzofuran	9	2 6 E-4						
fluorene	13	3 7 E-4	4 0 E-2	9 3 E-3				
hexachlorobenzene	ND		8 0 E-4	NA	4 6 E-5	NA		
phenanthrene	11	3 1 E-4						
anthracene	ND		3 0 E-1	NA				
fluoranthene	1	2 9 E-5	4 0 E-2	7 1 E-4				
pyrene	ND		3 0 E-2	NA				
benzo(A)anthracene	ND							
bis(2-ethylhexyl)phthalate	46	1 3 E-3	2 0 E-2	6 6 E-2	4 0 E-7	1 8 E-5		
chrysene	ND							
benzo(B)fluoranthene	ND							
beno)A)pyrene	ND				2 1 E-4	NA		
indeno(1,2,3-CD)pyrene	ND							
dibenzo(A,H)anthracene	ND							
benzo(GHI)perylene	ND							

(1) See Table 2-2
(2) Dose Rate assumes a consumption of 2 L of water per day per 70 kg adult
(3) See Table 4-2
(4) Noncancer Hazard Quotient = exposure level/reference dose
(5) Cancer Risk = concentration x unit risk
(6) HA = Health Advisory

TABLE 4-4 (Cont.)

Concentration/Toxicity Screening

Chemical Name	Max GW Conc (ug/L) (1)	Dose Rate (mg/kg/day) (2)	Oral RfD (mg/kg/day) (3)	Noncancer Hazard Quotient (4)	Oral Unit Risk (per ug/L) (3)	Cancer Risk (5)	1-Day HA (mg/L) (6)	10-Day HA (mg/L) (6)
Pesticides								
alpha-BHC	20	5 7 E-4			1 8 E-4	3 6 E-3		
beta-BHC	7	2 0 E-4			5 3 E-5	3 7 E-4		
delta-BHC	17	4 9 E-4						
gamma-BHC (Lindane)	17	4 9 E-4	3.0 E-4	1.6 E+0			1	1 2
aldrin	0.03	8 6 E-7	3.0 E-5	2 9 E-2	4 9 E-4	1 5 E-5		
4,4 DDE	3	8 6 E-5			9 7 E-6	2 9 E-5		
endrin	5	1 4 E-4	3.0 E-4	4 8 E-1				
endrin aldehyde	29	8 3 E-4						
heptachlor	0 1	2 9 E-6	5 0 E-4	5 7 E-3	1 3 E-4	1 3 E-5		0 01
PCB	ND				2 2 E-4	NA		
Metals								
arsenic	103	2 9 E-3	3 0 E-4	9 8 E+0	5 0 E-5	5 2 E-3		
chromium (7)	434	1 2 E-2	5 0 E-3	2 5 E+0				
copper	40	1 1 E-3					1 4	1 4
zinc	114	3 3 E-3	3 0 E-1	1 1 E-2				

(1) See Table 2-2
(2) Dose Rate assumes a consumption of 2 L of water per day per 70 kg adult
(3) See Table 4-2
(4) Noncancer Hazard Quotient = exposure level/reference dose
(5) Cancer Risk = concentration x unit risk
(6) HA = Health Advisory
(7) RfD value is for hexavalent chromium All Health Advisory values are based on total chromium (III and VI)

TABLE 4-5

Results of Toxicity and Fate/Transport Screening

Chemical Name	Max GW Conc (ug/L) (1)	Maximum Cancer Risk (2)	Percent of total Risk	Cumulative Percent of Risk	Noncancer Hazard Quotient (2)	Retained (3)
Potential Carcinogens						
1,2-dichloroethane	860,000	2 2 E+0	59 73%	59 73%		Yes
vinyl chloride	16,000	8 6 E-1	23 08%	82 80%		Yes
carbon tetrachloride	110,000	4 1 E-1	10 87%	93 68%	4 5 E+3	Yes
chloroform	850,000	1 4 E-1	3 86%	97 54%	2 4 E+3	Yes
1,1-dichloroethene	1,800	3 1 E-2	0 82%	98 35%	5 7 E+0	Yes
tetrachlororethene	20,146	2 9 E-2	0 79%	99 14%	5 8 E+1	Yes
methylene chloride	43,581	9 2 E-3	0 24%	99 38%	2 1 E+1	Yes
trichloroethene	18,957	6 0 E-3	0 16%	99 54%		Yes
arsenic	103	5 2 E-3	0 14%	99 68%	9 8 E+0	Yes
1,1,2,2-tetrachloroethane	674	3 9 E-3	0 10%	99 78%		No
alpha-BHC	20	3 6 E-3	0 10%	99 88%		No
benzene	3,800	3 2 E-3	0 08%	99 96%		Yes (4)
1,1,2-trichloroethane	556	8 9 E-4	0 02%	99 99%	4 0 E+0	Yes (5)
beta-BHC	7	3 7 E-4	0 01%	100 00%		No
hexachloroethane	140	5 6 E-5	0 00%	100 00%	4 0 E+0	No (6)
4,4 DDE	3	2 9 E-5	0 00%	100 00%		No
bis(2-ethylhexyl)phthalate	46	1 8 E-5	0 00%	100 00%	6 6 E-2	No
aldrin	0 03	1 5 E-5	0 00%	100 00%	2 9 E-2	No
heptachlor	0 1	1 3 E-5	0 00%	100 00%	5 7 E-3	No
chloromethane	12	4 4 E-6	0 00%	100 00%		No
Noncarcinogens						
1,2-dichloroethene (total) (7)	250,000				3 6 E+2	Yes
acetone	110,000				3 1 E+1	Yes
1,1-dichloroethane	33,000				9 4 E+0	Yes
chromium (8)	434				2 5 E+0	Yes
gamma-BHC (Lindane)	17				1 6 E+0	No (6)
endrin	5				4 8 E-1	No
2-butanone	4,400				2 1 E-1	No
ethylbenzene	690				2 0 E-1	No
toluene	1,200				1 7 E-1	No
naphthalene	200				1 4 E-1	No
4-methylphenol	17				9 7 E-2	No
phenol	1,200				5 7 E-2	No
vinyl acetate	1,500				4 3 E-2	No
xylene	1,533				2 2 E-2	No
1,2,4-trichlorobenzene	7				2 0 E-2	No
zinc	114				1 1 E-2	No
fluorene	13				9 3 E-3	No
acenaphthene	18				8 6 E-3	No
2-methylphenol	8				4 6 E-3	No
fluoranthene	1				7 1 E-4	No

(1) See Table 2-2
(2) See Table 4-4
(3) Carcinogenic chemicals retained if percent contribution to risk exceeds 0 05%
Noncarcinogenic chemicals retained if Hazard Quotient exceeds 1 0
(4) Chemical retained based on high concentration and high mobility in groundwater, despite not meeting criteria in (3)
(5) Chemical retained based on noncarcinogenic risk (i e Hazard Quotient exceeds 1 0)
(6) Chemical not retained based on low concentration and low mobility in groundwater despite meeting criteria in (3)
(7) Noncancer Hazard Quotient based on RfD value for trans-1 2 DCE
(8) Noncancer Hazard Quotient based on RfD value for hexavalent chromium

4.6.2 Fate and Transport Screening

A total of 17 chemicals were evaluated for fate and transport screening. Sixteen chemicals met the toxicological screening criteria noted in Section 4.6.1. In addition, benzene was retained, even though it did not meet the toxicological screening criteria, because of the high concentrations, prevalence and mobility of this chemical in groundwater at the site.

Fate and transport characteristics of chemicals detected in DNAPL-impacted areas of the site are presented and discussed in Section 3.5. The use of maximum groundwater concentrations for the concentration/toxicity screen also served as a fate and transport screen. Most constituents retained as chemicals of potential concern all have relatively high water solubilities and relatively low soil/water partitioning coefficients (K_{OC}) which result in moderate to high mobility in groundwater.

Only two of the 17 chemicals were eliminated on the basis of fate and transport considerations. Hexachloroethane and gamma-BHC (Lindane) met the criteria for risk screening based on the calculated noncancer Hazard Quotient exceeding unity. However, both chemicals have low mobility in groundwater due to a high $K_{OC.}$, and occur in relatively low concentrations at the site. Consequently, hexachloroethane and gamma-BHC were eliminated as a chemicals of potential concern on the basis of limited transport in groundwater and an insignificant contribution to overall risk relative to the more mobile organic constituents (Table 4-5).

The remaining 15 chemicals, (11 carcinogenic and 4 noncarcinogenic) were retained on the basis of the concentration/toxicity screen and consideration of mobility and prevalence in groundwater at the French Limited site (Table 4-5). These 15 chemicals are all moderately to highly mobile in groundwater and/or occur in significant concentrations at the French Limited site. They form the chemicals of potential concern that are considered in this Risk Evaluation.

Constituents such as 2-butanone, vinyl acetate, 4-methyl-2-pentanone, 2,4-dimethylphenol, acenaphthene, anthracene, benzo(A)anthracene, benzo(A)pyrene, chrysene and benzo(A)fluoranthene which are found in DNAPL or DNAPL-impacted soil but not in groundwater were not retained as chemicals of potential concern. All of these chemicals were found in relatively low concentrations in DNAPL or DNAPL-impacted soil. Furthermore, most of these constituents are non-volatile and have low mobility in groundwater. Nevertheless, these constituents would contribute to health risk for exposure to DNAPL or DNAPL-impacted soil. However, as noted in Section 3.5.1, direct exposure to DNAPL and DNAPL-impacted soils via dermal contact, incidental ingestion or inhalation of volatilized compounds is controlled or prevented by local conditions. These are therefore not considered realistic potential exposure pathways in this Risk Evaluation.

4.6.3 List of Chemicals of Potential Concern

After consideration of the concentration/toxicity screen and the fate and transport characteristics of the chemicals detected in DNAPL-impacted areas of the site, 15 constituents were retained as chemicals of potential concern. These constituents are listed in Table 4-5. A summary of noncarcinogenic toxicity information pertinent to risk characterization for these chemicals of potential concern is shown in Figure 4-6. Carcinogenic toxicity information for the chemicals of potential concern is summarized in Table 4-7.

4.7 Uncertainties Related to Toxicity Information

Toxicity information for many of the chemicals found at the French Limited site sites is limited. Consequently, there are varying degrees of uncertainty associated with the toxicity values calculated. Sources of uncertainty associated with toxicity values may include using:

- dose-response information from effects observed at high doses to predict the adverse health effects that may occur following exposure at the low levels expected during human contact with the agent in the environment;
- dose-response information from short-term exposure studies to predict the effects of long-term exposures, and vice-versa;
- dose-response information from animal studies to predict effects in humans; and
- dose-response information from homogeneous animal populations or healthy human populations to predict the effects likely to be observed in the general population consisting of individuals with a wide range of sensitivities.

An understanding of the degree of uncertainty associated with toxicity values is an important part of interpreting and using those values. The degree of confidence ascribed to a toxicity value is a function of both the quality of the individual study from which it was derived and the completeness of the supporting data base.

TABLE 4-6

Noncarcinogenic Toxicity Summary for Chemicals of Potential Concern

Chemical Name	CAS #	Oral RfD (mg/kg-day)	Inhalation RfC (mg/m3)	Source Notes (1)	Species	Route of Exposure	Critical Effect	Confidence Level	Uncertainty/ Modifying Factors
1,1,2-trichloroethane	79-00-5	4 0 E-3			mouse	drinking water	Liver toxicity	medium	1000/1
1,1-dichloroethane	75-34-3	1 0 E-1		(2)	rat	inhalation	none	medium	1,000
			5 0 E-1	(2)	cat	inhalation	kidney damage	NA	1,000
1,1-dichloroethene	75-35-4	9 0 E-3			rat	drinking water	Hepatic lesions	medium	1000/1
1,2-dichloroethane	107-06-2				NA	NA	NA	NA	NA
1,2-dichloroethene (total) (4)	156-60-5	2 0 E-2		(4)	mouse	drinking water	Increased alkaline phosphatase	low	1000/1
acetone	67-64-1	1 0 E-1			rat	gavage	Increased liver & kidney wt , kidney toxicity	low	1000/1
arsenic	7440-38-2	3 0 E-4			human	oral	Keratosis & hyperpigmentation	NA	1
benzene	71-43-2				NA	NA	NA	NA	NA
carbon tetrachloride	56-23-5	7 0 E-4			rat	gavage	Liver lesions	medium	1000/1
chloroform	67-66-3	1 0 E-2			dog	oral	Fatty cists in liver	medium	1000/1
chromium (5)	18540-29-9	5 0 E-3		(5)	rat	drinking water	No effects reported	low	500/1
methylene chloride	75-09-2	6 0 E-2			rat	drinking water	Liver toxicity	medium	100/1
			3 0 E+0	(3)	rat	inhalation	liver toxicity	NA	100
tetrachlororethene (PCE)	127-18-4	1 0 E-2		(3)	mouse	gavage	Heptatoxicity, weight gain	NA	1000/1
trichloroethene (TCE)	79-01-6				NA	NA	NA	NA	NA
vinyl chloride	75-01-4				NA	NA	NA	NA	NA

(1) All toxicological data obtained from IRIS database (as of April, 1994) unless otherwise noted
(2) Obtained from U S EPA, "Health Effects Assessment Summary Tables," Annual, FY-1993, OERR PB93-921199 March, 1993
(3) Obtained from U S EPA, "Health Effects Assessment Summary Tables," Fourth Quarter, FY-1990, OSWER PB90-921104
(4) Noncancer Hazard Quotient based on RfD value for trans-1,2-DCE
(5) Noncancer Hazard Quotient based on RfD value for hexavalent chromium

TABLE 4-7

Carcinogenic Toxicity Summary for Chemicals of Potential Concern

Chemical Name	CAS #	Carc Class (1)	Oral Slope Factor mg/kg-dy $^{-1}$	Inhalation Unit Risk (per ug/m3)	Source Notes (2)	Species	Route of Exposure	Type of Cancer	Developmental Toxicity
1,1,2-trichloroethane	79-00-5	C	5 7 E-2			mouse	gavage	Hepatocellular carcinomas & pheochromocytomas	no indications
				1 6 E-5		mouse	gavage	Hepatocellular carcinomas & pheochromocytomas	
1,1-dichloroethane	75-34-3	C			(3)	mouse	gavage	no indications	no indications
1,1-dichloroethene	75-35-4	C	6 0 E-1			rat	drinking water	Adrenal pheochromocytomas	fetotoxic
				5 0 E-5		mouse	inhalation	Kidney adenoscarcomas	
1,2-dichloroethane	107-06-2	B2	9 1 E-2			rat	gavage	Hemangiosarcomas	no indications
				2 6 E-5		rat	gavage	Hemangiosarcomas	
1,2-dichloroethene (total)	156-60-5				(5)	NA	NA	NA	no indications
acetone	67-64-1	D				NA	NA	NA	no indications
arsenic	7440-38-2	A	1 8 E+0			human	drinking water	Skin,bladder, lung, kidney & colon	malformations
		A		4 3 E-3		human	inhalation	lung cancer	
benzene	71-43-2	A	2 9 E-2			human	inhalation	Leukemia	no indications
		A		8 3 E-6		human	inhalation	Leukemia	
carbon tetrachloride	56-23-5	B2	1 3 E-1			hamster	gavage	Hepatocellular carcinomas/hepatomas	no indications
		B2		1 5 E-5		*hamster*	*gavage*	*Hepatocellular carcinomas/hepatomas*	
chloroform	67-66-3	B2	6 1 E-3			rat	drinking water	Kidney tumors (males)	no indications
		B2		2 3 E-5		mouse	gavage	Hepatocellular carcinoma (females)	
chromium	18540-29-9	A		1 2 E-2	(6)	human	inhalation	lung cancer	
methylene chloride	75-09-2	B2	7 5 E-3			mouse	drinking water	Hepatocellular adenomas	no indications
		B2		4 7 E-7		mouse	inhalation	Liver and lung adenomas & carcinomas	
tetrachlororethene (PCE)	127-18-4	B2	5 1 E-2		(4)	mouse	gavage	Liver tumors	no indications
		B2		9 4 E-7	(4)	mouse	gavage	Leukemia, liver	
trichloroethene (TCE)	79-01-6	B2	1 1 E-2		(4)	mouse	gavage	Liver tumors	no indications
		B2		4 8 E-6	(4)	mouse	gavage	Leukemia, liver	
vinyl chloride	75-01-4	A	1 9 E+0		(3)	rat	diet	Lung tumors	no indications
		A		8 4 E-5	(3)	rat	inhalation	Lung tumors	

(1) For Carcinogen Class explanation see Table 4-1
(2) All toxicological data obtained from IRIS database (as of April, 1994) unless otherwise noted
(3) Obtained from U S EPA, "Health Effects Assessment Summary Tables," Annual, FY-1993, OERR PB93-921199 March, 1993
(4) Obtained from U S EPA, "Health Effects Assessment Summary Tables," Fourth Quarter, FY-1990, OSWER PB90-921104
(5) Carcinogenicity values based on trans-1,2-DCE
(6) Carcinogenicity values based on chromium VI

4.7.1 Uncertainties Related to EPA Non-Carcinogenic Toxicity Information

Toxicological data used in this toxicity assessment were obtained exclusively from EPA sources. EPA-verified RfDs found in IRIS are accompanied by a statement of the confidence that the evaluators have in the RfD itself, the critical study, and the overall data base. Uncertainty in the toxicity information is addressed by applying an uncertainty factor to the RfD estimate. This results in a bias toward higher risks. Thus the greater the degree of uncertainty, the more the risk calculations are biased toward overestimating risk.

1,1-DCA was the only constituent retained as a chemical of potential concern for non-carcinogenic risk calculations which was not found in IRIS. The toxicity information for 1,1-DCA is under review by EPA. It was considered preferable to use the toxicity information from HEAST (EPA, 1993) rather than to ignore this chemical in the quantitative risk calculations even though its status suggests greater uncertainty in the RfD.

4.7.2 Uncertainties Related to EPA Carcinogenic Toxicity Information

Toxicological data used in this toxicity assessment for carcinogenic risk calculations were obtained exclusively from EPA sources. EPA-verified slope factors found in IRIS are accompanied by EPA's weight-of-evidence classification for carcinogenicity based on the completeness of the evidence that the agent causes cancer in experimental animals and humans. These designations for all DNAPL-related chemicals found in the IRIS data base are summarized in Table 4-2. All chemicals of potential concern retained for carcinogenic risk calculations except 1,1-DCE, are either human carcinogens (Class A) or probable human carcinogens (Class B2). Even though 1,1-DCE is classified as a possible human carcinogen (i.e. Class C), it is still retained for carcinogenic risk calculations due to its relatively high concentration in groundwater. Chemicals which are not classifiable (Class D) or for which no toxicity information are available are not considered in the quantitative risk calculations

EPA employs a slope factor value at the upper 95 percent confidence limit of the range of possible slope factors. Animal data selected for use in the linearized multistage dose-response model used to extrapolate cancer risk are often obtained from the most sensitive species of experimental animals. The study which gives the highest level of extrapolated risks (when more than one study is available) are used to derive potential human doses using a scaling factor that assumes that humans are more sensitive. All EPA-verified slope factors are accompanied by a weight-of-evidence classification, which indicates the likelihood that the agent is a human carcinogen. These assumptions and procedures are designed to avoid underestimating risk and the greater the uncertainty, the more the results are biased toward higher carcinogenic risks

Three constituents retained as chemicals of potential concern for carcinogenic risk calculations, 1,1-DCE, PCE and vinyl chloride, are not found in IRIS. The toxicity information for these constituents is under review by EPA. It was considered preferable to use the toxicity information from HEAST (EPA, 1990 for PCE and EPA, 1993 for 1,1-DCE and vinyl chloride) rather than to ignore these chemicals in the quantitative risk calculations. The review status of these chemicals indicates greater uncertainty in the slope factor and/or weight of evidence classification. This greater uncertainty is not explicitly considered in the risk analysis methodology which would typically err on the side of higher estimated risk.

4.7.3 Chemicals with No Available Toxicity Values

EPA-derived RfDs and slope factors are not available for fifteen chemicals that were included in Table 2-2 as DNAPL-related chemicals at the French Limited Site. Due to the relatively low concentrations for these constituents in groundwater and the lack of evidence that they pose a health risk, these constituents are not expected to represent a significant potential health risk that would warrant their inclusion as chemicals of potential concern for the Risk Evaluation. Unlike most methods used to deal with uncertainty in the toxicity assessment, uncertainty resulting from not explicitly considering these chemicals in the risk analysis would actually bias the results toward lower estimated risk. However, as indicated above, the incremental contribution of these chemicals to overall risk is minimal.

These chemicals which are not included in the quantitative risk assessment are discussed below.

chloromethane	A risk assessment for chloromethane is under review by EPA. It has been classified in EPA (1992) as a possible human carcinogen (Class C). The maximum concentration observed in groundwater was 12 ug/l and it was not detected in DNAPL or soil in DNAPL-impacted areas.
4-methyl-2-pentanone	The oral RfD for 4-methyl-2-pentanone has been withdrawn and inadequate data exists for assessment of an inhalation RfC for groundwater vapors. Data on carcinogenicity are not available. The 4-methyl-2-pentanone groundwater cleanup criteria at the site is 1,750 ug/l. 4-methyl-2-pentanone was detected in the DNAPL but was not detected in groundwater or soil in DNAPL-impacted areas.

4-methylphenol	The oral RfD for 4-methylphenol has been withdrawn and inadequate data exists for assessment of an inhalation RfC groundwater or a slope factor for carcinogenicity. 4-methylphenol is classified as a possible human carcinogen (Class C). 4-methylphenol was detected in groundwater in DNAPL-impacted areas at a maximum concentration of 27 ug/l but was not detected in DNAPL or in soil in DNAPL-impacted areas.
2-methynaphthalene	EPA toxicity information does not exist for 2-methynaphthalene. 2-methynaphthalene was detected in groundwater in DNAPL-impacted areas at a maximum concentration of 27 ug/l and was also detected in DNAPL and in soil in DNAPL-impacted areas. Naphthalene, which is a potential surrogate for 2-methynaphthalene, was found at a maximum concentration in groundwater of 110 ug/l and was eliminated in the concentration/toxicity screen.
acenaphthylene	The oral RfD for acenaphthylene is under review by EPA and no data exists for assessment of an inhalation RfC. Acenaphthylene is not classifiable as to human carcinogenicity (Class D). Acenaphthylene was not detected in groundwater in DNAPL-impacted areas but was detected in DNAPL and in soil in DNAPL-impacted areas at relatively low concentrations.
dibenzofuran	The inhalation RfC assessment for dibenzofuran is under review by EPA and no data exists for assessment of an oral RfD. Dibenzofuran is not classifiable as to human carcinogenicity (Class D). Dibenzofuran was detected in groundwater in DNAPL-impacted areas at a maximum concentration of 26 ug/l and was also detected in DNAPL and in soil in DNAPL-impacted areas.

phenanthrene	No data exists for assessment of an oral RfD or inhalation RfC groundwater for phenanthrene. Phenanthrene is not classifiable as to human carcinogenicity (Class D). Phenanthrene was detected in groundwater in DNAPL-impacted areas at a maximum concentration of 29 ug/l and was also detected in DNAPL and in soil in DNAPL-impacted areas. Anthracene, which is a potential surrogate for phenanthrene, has an RfD of 0.003 mg/kg-day. Using this RfD and the maximum detected phenanthrene concentration in groundwater yields a Noncancer Hazard Quotient of 0.28 and would be eliminated in a concentration/toxicity screen
benzo(A)anthracene	No data exists for assessment of an oral RfD or inhalation RfC groundwater for benzo(A)anthracene. This chemical is classified as a probable human carcinogen (Class B2). No data exists for assessment of a slope factor for carcinogenic risk calculations. Benzo(A)anthracene was detected in soil in DNAPL-impacted areas at a maximum concentration of 46 mg/kg but was not detected in DNAPL or in groundwater in DNAPL-impacted areas.
chrysene	No data exists for assessment of an oral RfD or inhalation RfC groundwater for chrysene. Chrysene is classified as a probable human carcinogen (Class B2). No data exists for assessment of a slope factor for carcinogenic risk calculations. Chrysene was detected in soil in DNAPL-impacted areas at a maximum concentration of 71 mg/kg but was not detected in DNAPL or in groundwater in DNAPL-impacted areas.
benzo(B)fluoranthene	No data exists for assessment of an oral RfD or inhalation RfC groundwater for benzo(B)fluoranthene. This chemical is classified as a probable human carcinogen (Class B2). No data exists for assessment of a slope factor for carcinogenic risk calculations. Benzo(B)fluoranthene was detected in soil in DNAPL-impacted areas at a maximum concentration of 20 mg/kg but was not detected in DNAPL or in groundwater in DNAPL-impacted areas.

indeno(1,2,3-CD)pyrene	No data exists for assessment of an oral RfD or inhalation RfC groundwater for indeno(1,2,3-CD)pyrene. This chemical is classified as a probable human carcinogen (Class B2). No data exists for assessment of a slope factor for carcinogenic risk calculations. Indeno(1,2,3-CD)pyrene was detected in soil in DNAPL-impacted areas at a maximum concentration of 0.44 mg/kg but was not detected in DNAPL or in groundwater in DNAPL-impacted areas.
dibenzo(A,H)anthracene	No data exists for assessment of an oral RfD or inhalation RfC groundwater for dibenzo(A,H)-anthracene. This chemical is classified as a probable human carcinogen (Class B2). No data exists for assessment of a slope factor for carcinogenic risk calculations. Dienzo(A,H)anthracene was detected in soil in DNAPL-impacted areas at a maximum concentration of 0.25 mg/kg but was not detected in DNAPL or in groundwater in DNAPL-impacted areas.
benzo(GHI)perylene	No data exists for assessment of an oral RfD or inhalation RfC groundwater for benzo(GHI)perylene. Benzo(GHI)perylene is not classifiable as to human carcinogenicity (Class D). No data exists for assessment of a slope factor for carcinogenic risk calculations. Benzo(GHI)perylene was detected in soil in DNAPL-impacted areas at a maximum concentration of 3.0 mg/kg but was not detected in DNAPL or in groundwater in DNAPL-impacted areas.
aluminum	Aluminum is not in the IRIS data base. No data exists for a risk assessment. Aluminum was detected in groundwater in DNAPL-impacted areas at a maximum concentration of 300 ug/l but was not analyzed in DNAPL or soil samples.
vanadium	The oral RfD for vanadium is under review by EPA and no data exists for assessment of an inhalation RfC Data on carcinogenicity are not available. Vanadium was detected in groundwater in DNAPL-impacted areas at a maximum concentration of 300 ug/l but was not analyzed in DNAPL or soil samples.

Currently it is not possible to evaluate quantitatively the contribution of these chemicals to the overall risk.

5.0 RISK CHARACTERIZATION

This section describes the procedures and results of the final step of the risk assessment process, risk characterization. In this step, the toxicity and exposure assessments are summarized and integrated into quantitative and qualitative expressions of risk. To characterize potential noncarcinogenic effects, comparisons were made between projected intakes of substances and toxicity values To characterize potential carcinogenic effects, probabilities that an individual will develop cancer over a lifetime of exposure are estimated from projected intakes and chemical-specific dose-response information. Major assumptions, scientific judgments, and to the extent possible, estimates of the uncertainties embodied in the assessment are also presented.

The risk characterization methods used in this study conformed to the EPA-approved work plan (AHA, 1993) which was developed to be consistent with EPA's most recent risk assessment guidelines (EPA, 1989c).

5.1 Risk Characterization Process

Figure 5-1 is an overview of the risk characterization process, and illustrates how it relates to the preceding toxicity and exposure assessments (Sections 3.0 and 4.0). This section describes the steps that were used for quantifying risk or hazard indices for both carcinogenic and noncarcinogenic effects to be applied to each exposure pathway analyzed.

5.1.1 Calculation of Risks for Individual Substances

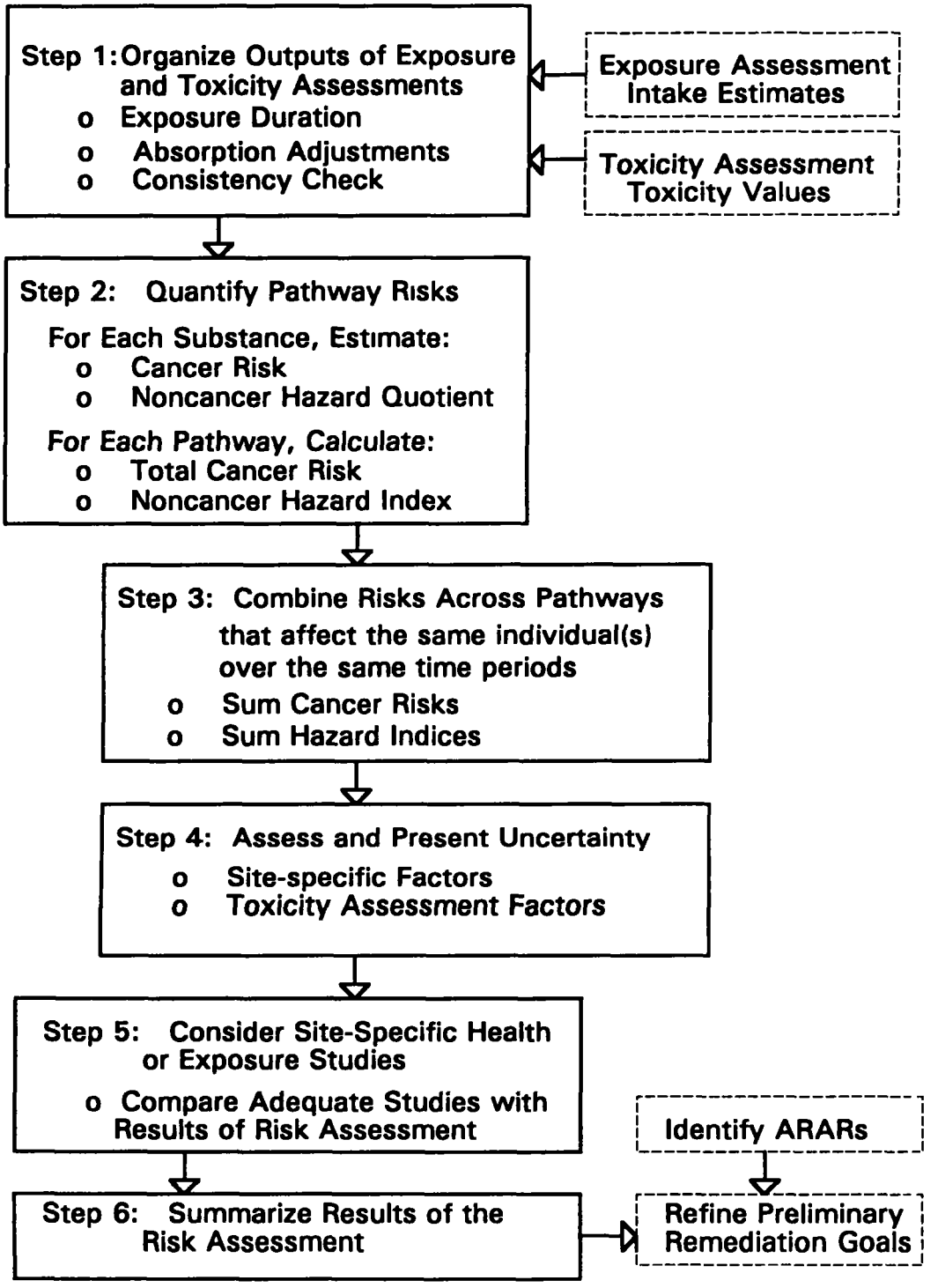
Carcinogenic Effects

For carcinogens, risks are estimated as the incremental probability of an individual developing cancer over a lifetime as a result of exposure to the potential carcinogen (i.e., incremental or excess individual lifetime cancer risk). The methodology used is consistent with EPA's (1986a) *Guidelines for Carcinogen Risk Assessment.*

The slope factor (SF) converts estimated daily intakes averaged over a lifetime of exposure to incremental risk of an individual developing cancer. Because relatively low intakes (compared to those experienced by test animals) are most likely from environmental exposures at the French Limited site, it generally can be assumed that the dose-response relationship is linear in the low-dose portion of the multistage model dose-response curve. Based on this assumption, the slope factor is a constant, and risk is directly related to intake. (See Section 4.0)

FIGURE 5-1

STEPS IN RISK CHARACTERIZATION



Following EPA guidance, the linear form of the carcinogenic risk equation is used for estimating risks at the French Limited site. This linear low-dose equation is described as follows:

Linear Low-Dose Cancer Risk Equation

$$Risk = CDI \times SF$$

where:

Risk = a unitless probability (e.g., 1×10^{-6}) of an individual developing cancer;

CDI = chronic daily intake averaged over 70 years (mg/kg-day); and

SF = slope factor, expressed in $(mg/kg\text{-}day)^{-1}$

The carcinogenic risk estimate will generally be an upper-bound estimate, because the slope factor is often an upper 95th percentile confidence limit of the probability of response based on experimental animal data used in the multistage model. This means that there is reasonable confidence that the "true risk" will not exceed the risk estimate derived through use of this model and is likely to be less than that predicted.

The results of applying the carcinogenic cancer risk equation to the potential future groundwater exposure scenarios developed for receptor locations north of Gulf Pump Road (at the INT-11 and S1-13 Areas), at the Riverdale Subdivision and south of the New Hwy. 90 are summarized in Tables 5-1, 5-2, 5-3 and 5-4 respectively. It can be seen that, in the absence of remedial responses that contain or control DNAPL-impacted source area contributions to the groundwater, there is a potential future risk associated with exposures to contaminated groundwater at all these receptor locations. Aside from arsenic and chromium, that were not detected in the source areas for these pathways, all the potential carcinogenic chemicals-of-concern have calculated future concentrations in groundwater at the receptor locations that exceed the calculated 10^{-6} excess cancer risk for drinking water ingestion under the Reasonable Maximum Exposure (RME) scenarios described in Section 3.0. Similarly, for most of the carcinogenic chemicals-of-concern, the calculated 10^{-6} excess cancer risk is exceeded for inhalation exposure using a showering scenario. The only exceptions are for arsenic and chromium (which are non-volatile and were not detected in the source areas) and carbon tetrachloride at the receptor location north of Gulf Pump Road near the S1-13 Area

TABLE 5-1

Calculated Risk for Groundwater Exposure North of Gulf Pump Road near INT-11 Area

Media: Groundwater
Land Use: Future
Exposed Population Residential
Exposure Pathway Ingestion of groundwater that has migrated from the site to downgradient water wells

Chemical Name	Exposure Concentration (1) (ug/L)	Time for First Detection (2) (days)	Time for 95% of Max. (2) (days)	Chronic Daily Intake (3) (mg/kg-day)	Oral RfD (mg/kg-day)	Noncancer Hazard Quotient (4)	Oral Slope Factor (mg/kg-day)	Cancer Risk (5)	1-Day HA (6) (mg/L)	10-Day HA (6) (mg/L)
vinyl chloride	7,278	19	118	8 9 E-2			1 9 E+0	2 E-1		
methylene chloride	43,581	8	38	5 3 E-1	6 0 E-2	21	7 5 E-3	4 E-3	13 30	1 50
acetone	76,036	3	27	9 3 E-1	1 0 E-1	22				
1,1-dichloroethene	1,137	27	132	1 4 E-2	9 0 E-3	4	6 0 E-1	8 E-3		
1,1-dichloroethane	5,658	15	73	6 9 E-2	1 0 E-1	2				
1,2-dichloroethene (total)	63,613	25	122	7 8 E-1	2 0 E-2	90				
chloroform	131,131	10	75	1 6 E+0	1 0 E-2	400	6 1 E-3	1 E-2		
1,2-dichloroethane	20,000	9	46	2 4 E-1			9 1 E-2	2 E-2		
carbon tetrachloride	2	42	207	2 4 E-5	7 0 E-4	0 08	1 3 E-1	3 E-6	4 00	0 16
trichloroethene	18,957	48	234	2 3 E-1			1 1 E-2	3 E-3		
1,1,2-trichloroethane	556	24	117	6 8 E-3	4 0 E-3	4	5 7 E-2	4 E-4	0 60	0 40
benzene	1,300	35	162	1 6 E-2			2 9 E-2	5 E-4		0 24
tetrachlororethene	9,474	130	632	1 2 E-1	1 0 E-2	27	5 1 E-2	6 E-3		2 00
arsenic	40	NA	NA	NA	3 0 E-4	NA	1 8 E+0	NA		
chromium	ND	NA	NA	NA	5 0 E-3	NA		NA	1 40	1 40
Total Pathway Risk =						**570**		**2 E-1**		

Notes

(1) For exposure concentrations and intakes see Table 3-4 and Appendix B
(2) Based on modeling of selected chemicals and extrapolation for remaining chemicals
(3) Chronic Daily Intake (CDI) averaged over 70 year lifetime
(4) Noncancer Hazard Quotient = exposure level/reference dose Exposure level adjusted for exposure duration (30 yrs)
(5) Cancer Risk = Chronic Daily Intake (CDI) x Slope Factor
(6) HA = health advisory for drinking water

TABLE 5-1 (Cont.)

Calculated Risk for Groundwater Exposure North of Gulf Pump Road near INT-11 Area

Media: Air
Land Use Future
Exposed Population: Residential
Exposure Pathway: Inhalation of chemicals that have volatilized from groundwater during showering

Chemical Name	Exposure Concentration (1) mg/m3	Chronic Daily Intake (2) (mg/kg-day)	Inhalation RfC (mg/kg-day)	Noncancer Hazard Quotient (3)	Inhalation Unit Risk (m3/ug)	Inhalation Slope Factor (kg-day)/mg	Cancer Risk (4)
vinyl chloride	60	4 4 E-2			8 4 E-5	2 9 E-1	1 E-2
methylene chloride	245	1 8 E-1			4 7 E-7	1 6 E-3	3 E-4
acetone	83	6 1 E-2	3 0 E+0	0 05			
1,1-dichloroethene	15	1 1 E-2			5 0 E-5	1 8 E-1	2 E-3
1,1-dichloroethane	266	2 0 E-1					
1,2-dichloroethene (total)	2,060	1 5 E+0	5 0 E-1	0 00			
chloroform	6,213	4 6 E+0			2 3 E-5	8 1 E-2	4 E-1
1,2-dichloroethane	6,021	4 4 E+0			2 6 E-5	9 1 E-2	4 E-1
carbon tetrachloride	768	5 6 E-1			1 5 E-5	5 3 E-2	3 E-2
trichloroethene	48	3 5 E-2			4 8 E-6	1 7 E-2	6 E-4
1,1,2-trichloroethane	0	2 7 E-5			1 6 E-5	5 6 E-2	2 E-6
benzene	11	7 9 E-3			8 3 E-6	2 9 E-2	2 E-4
tetrachlororethene	136	1 0 E-1			9 4 E-7	3 3 E-3	3 E-4
arsenic	ND	NA			4 3 E-3	1 5 E+1	NA
chromium	ND	NA			1 2 E-2	4 2 E+1	NA
				Total Pathway Risk =	0 05		8 E-1

Notes

(1) *For exposure concentrations and intakes see Table 3-4 and Appendix B*
(2) Chronic Daily Intake (CDI) averaged over 70 year lifetime
(3) Noncancer Hazard Quotient = exposure level/reference dose Exposure level adjusted for exposure duration (30 yrs)
(4) Cancer Risk = Chronic Daily Intake (CDI) x Slope Factor

Total Ingestion and Inhalation Pathway Risk =	7,400	2 E+0

TABLE 5-2

Calculated Risk for Groundwater Exposure North of Gulf Pump Road near S1-13 Area

Media: Groundwater
Land Use: Future
Exposed Population: Residential
Exposure Pathway Ingestion of groundwater that has migrated from the site to downgradient water wells

Chemical Name	Exposure Concentration (1) (ug/L)	Time for First Detection (2) (days)	Time for 95% of Max (2) (days)	Chronic Daily Intake (3) (mg/kg-day)	Oral RfD (mg/kg-day)	Noncancer Hazard Quotient (4)	Oral Slope Factor (mg/kg-day)	Cancer Risk (5)	1-Day HA (6) (mg/L)	10-Day HA (6) (mg/L)
vinyl chloride	6,000	5	814	7 3 E-2			1 9 E+0	1 E-1		
methylene chloride	30,000	2	219	3 7 E-1	6 0 E-2	14	7 5 E-3	3 E-3	13 30	1 50
acetone	81,000	1	31	9 9 E-1	1 0 E-1	23				
1,1-dichloroethene	1,800	5	766	2 2 E-2	9 0 E-3	6	6 0 E-1	1 E-2		
1,1-dichloroethane	33,000	3	426	4 0 E-1	1 0 E-1	9				
1,2-dichloroethene (total)	250,000	5	708	3 1 E+0	2 0 E-2	360				
chloroform	850,000	1	435	1 0 E+1	1 0 E-2	2,400	6 1 E-3	6 E-2		
1,2-dichloroethane	860,000	1	200	1 1 E+1			9 1 E-2	1 E+0		
carbon tetrachlonde	110,000	9	1204	1 3 E+0	7 0 E-4	4,500	1 3 E-1	2 E-1	4 00	0 16
trichloroethene	6,500	10	1360	8 0 E-2			1 1 E-2	9 E-4		
1,1,2-trichloroethane	5	5	679	6 1 E-5	4 0 E-3	0 04	5 7 E-2	3 E-6	0 60	0 40
benzene	1,200	10	1186	1 5 E-2			2 9 E-2	4 E-4		0 24
tetrachlororethene	20,146	26	3677	2 5 E-1	1 0 E-2	58	5 1 E-2	1 E-2		2 00
arsenic	ND	NA	NA	NA	3 0 E-4	NA	1 8 E+0	NA		
chromium	ND	NA	NA	NA	5 0 E-3	NA		NA	1 40	1 40

Total Pathway Risk =	7,400	1 E+0

Notes

(1) For exposure concentrations and intakes see Table 3-4 and Appendix B
(2) Based on modeling of selected chemicals and extrapolation for remaining chemicals
(3) Chronic Daily Intake (CDI) averaged over 70 year lifetime
(4) *Noncancer Hazard Quotient = exposure level/reference dose* Exposure level adjusted for exposure duration (30 yrs)
(5) Cancer Risk = Chronic Daily Intake (CDI) x Slope Factor
(6) HA = health advisory for drinking water

TABLE 5-2 (Cont.)

Calculated Risk for Groundwater Exposure North of Gulf Pump Road near S1-13 Area

Media: Air
Land Use Future
Exposed Population Residential
Exposure Pathway Inhalation of chemicals that have volatilized from groundwater during showering

Chemical Name	Exposure Concentration (1) mg/m3	Chronic Daily Intake (2) (mg/kg-day)	Inhalation RfC (mg/kg-day)	Noncancer Hazard Quotient (3)	Inhalation Unit Risk (m3/ug)	Inhalation Slope Factor (kg-day)/mg	Cancer Risk (4)
vinyl chloride	73	5 3 E-2			8 4 E-5	2 9 E-1	2 E-2
methylene chloride	355	2 6 E-1			4 7 E-7	1 6 E-3	4 E-4
acetone	77	5 7 E-2	3 0 E+0	0 04			
1,1-dichloroethene	10	7 0 E-3			5 0 E-5	1 8 E-1	1 E-3
1,1-dichloroethane	46	3 3 E-2					
1,2-dichloroethene (total)	524	3 9 E-1	5 0 E-1	0 00			
chloroform	959	7 0 E-1			2 3 E-5	8 1 E-2	6 E-2
1,2-dichloroethane	140	1 0 E-1			2 6 E-5	9 1 E-2	9 E-3
carbon tetrachloride	0 01	1 0 E-5			1 5 E-5	5 3 E-2	5 E-7
trichloroethene	140	1 0 E-1			4 8 E-6	1 7 E-2	2 E-3
1,1,2-trichloroethane	4	3 0 E-3			1 6 E-5	5 6 E-2	2 E-4
benzene	12	8 5 E-3			8 3 E-6	2 9 E-2	2 E-4
tetrachlororethene	64	4 7 E-2			9 4 E-7	3 3 E-3	2 E-4
arsenic	ND	NA			4 3 E-3	1 5 E+1	NA
chromium	ND	NA			1 2 E-2	4 2 E+1	NA
			Total Pathway Risk =	0 04			9 E-2

Notes

(1) For exposure concentrations and intakes see Table 3-4 and Appendix B
(2) Chronic Daily Intake (CDI) averaged over 70 year lifetime
(3) Noncancer Hazard Quotient = exposure level/reference dose Exposure level adjusted for exposure duration (30 yrs)
(4) Cancer Risk = Chronic Daily Intake (CDI) x Slope Factor

Total Ingestion and Inhalation Pathway Risk =	570	3 E-1

TABLE 5-3

Calculated Risk for Groundwater Exposure at Riverdale Subdivision

Media: Groundwater
Land Use: Future
Exposed Population Residential
Exposure Pathway: Ingestion of groundwater that has migrated from the site to downgradient water wells

Chemical Name	Exposure Concentration (1) (ug/L)	Time for First Detection (2) (days)	Time for 95% of Max (2) (days)	Chronic Daily Intake (3) (mg/kg-day)	Oral RfD (mg/kg-day)	Noncancer Hazard Quotient (4)	Oral Slope Factor (mg/kg-day)	Cancer Risk (5)	1-Day HA (6) (mg/L)	10-Day HA (6) (mg/L)
vinyl chloride	16,000	15	34	2 0 E-1			1 9 E+0	4 E-1		
methylene chloride	640	7	11	7 8 E-3	6 0 E-2	0 30	7 5 E-3	6 E-5	13 30	1 50
acetone	110,000	7	8	1 3 E+0	1 0 E-1	31 43				
1,1-dichloroethene	160	24	38	2 0 E-3	9 0 E-3	0 51	6 0 E-1	1 E-3		
1,1-dichloroethane	3,300	13	21	4 0 E-2	1 0 E-1	0 94				
1,2-dichloroethene (total)	6,200	22	35	7 6 E-2	2 0 E-2	8 86				
chloroform	250	15	21	3 1 E-3	1 0 E-2	0 71	6 1 E-3	2 E-5		
1,2-dichloroethane	8,700	10	13	1 1 E-1			9 1 E-2	1 E-2		
carbon tetrachloride	66	38	59	8 1 E-4	7 0 E-4	2 69	1 3 E-1	1 E-4	4 00	0 16
trichloroethene	680	43	67	8 3 E-3			1 1 E-2	9 E-5		
1,1,2-trichloroethane	550	21	33	6 7 E-3	4 0 E-3	3 93	5 7 E-2	4 E-4	0 60	0 40
benzene	3,600	24	46	4 4 E-2			2 9 E-2	1 E-3		0 24
tetrachlororethene	77	115	181	9 4 E-4	1 0 E-2	0 22	5 1 E-2	5 E-5		2 00
arsenic	103	NA	NA	NA	3 0 E-4	NA	1 8 E+0	NA		
chromium	ND	NA	NA	NA	5 0 E-3	NA		NA	1 40	1 40
Total Pathway Risk =						**50**		**4 E-1**		

Notes

(1) For exposure concentrations and intakes see Table 3-4 and Appendix B
(2) Based on modeling of selected chemicals and extrapolation for remaining chemicals
(3) Chronic Daily Intake (CDI) averaged over 70 year lifetime
(4) Noncancer Hazard Quotient = exposure level/reference dose Exposure level adjusted for exposure duration (30 yrs)
(5) Cancer Risk = Chronic Daily Intake (CDI) x Slope Factor
(6) HA = health advisory for drinking water

TABLE 5-3 (Cont.)

Calculated Risk for Groundwater Exposure at Riverdale Subdivision

Media: Air
Land Use: Future
Exposed Population: Residential
Exposure Pathway: Inhalation of chemicals that have volatilized from groundwater during showering

Chemical Name	Exposure Concentration (1) mg/m3	Chronic Daily Intake (2) (mg/kg-day)	Inhalation RfC (mg/kg-day)	Noncancer Hazard Quotient (3)	Inhalation Unit Risk (m3/ug)	Inhalation Slope Factor (kg-day)/mg	Cancer Risk (4)
vinyl chloride	160	1 2 E-1			8 4 E-5	2 9 E-1	3 E-2
methylene chloride	5 2	3 8 E-3			4 7 E-7	1 6 E-3	6 E-6
acetone	112	8 2 E-2	3 0 E+0	0 06			
1,1-dichloroethene	1 4	9 9 E-4			5 0 E-5	1 8 E-1	2 E-4
1,1-dichloroethane	27	2 0 E-2					
1,2-dichloroethene (total)	51	3 8 E-2	5 0 E-1	0 00			
chloroform	1 8	1 3 E-3			2 3 E-5	8 1 E-2	1 E-4
1,2-dichloroethane	61	4 5 E-2			2 6 E-5	9 1 E-2	4 E-3
carbon tetrachloride	0 5	3 4 E-4			1 5 E-5	5 3 E-2	2 E-5
trichloroethene	5 0	3 7 E-3			4 8 E-6	1 7 E-2	6 E-5
1,1,2-trichloroethane	4 1	3 0 E-3			1 6 E-5	5 6 E-2	2 E-4
benzene	32	2 4 E-2			8 3 E-6	2 9 E-2	7 E-4
tetrachlororethene	0 5	3 8 E-4			9 4 E-7	3 3 E-3	1 E-6
arsenic	ND	NA			4 3 E-3	1 5 E+1	NA
chromium	ND	NA			1 2 E-2	4 2 E+1	NA
		Total Pathway Risk =		0 06			4 E-2

Notes

(1) For exposure concentrations and intakes see Table 3-4 and Appendix B
(2) Chronic Daily Intake (CDI) averaged over 70 year lifetime
(3) *Noncancer Hazard Quotient = exposure level/reference dose Exposure level adjusted for exposure duration (30 yrs)*
(4) Cancer Risk = Chronic Daily Intake (CDI) x Slope Factor

Total Ingestion and Inhalation Pathway Risk =	50	4 E-1

TABLE 5-4

Calculated Risk for Groundwater Exposure South of New Hwy. 90 (Crosby Freeway)

Media: Groundwater
Land Use: Future
Exposed Population Residential
Exposure Pathway: Ingestion of groundwater that has migrated from the site to downgradient water wells

Chemical Name	Exposure Concentration (1) (ug/L)	Time for First Detection (2) (days)	Time for 95% of Max. (2) (days)	Chronic Daily Intake (3) (mg/kg-day)	Oral RfD (mg/kg-day)	Noncancer Hazard Quotient (4)	Oral Slope Factor (mg/kg-day)	Cancer Risk (5)	1-Day HA (6) (mg/L)	10-Day HA (6) (mg/L)
vinyl chloride	6,639	80	125	8 1 E-2			1 9 E+0	2 E-1		
methylene chloride	36,791	32	40	4 5 E-1	6 0 E-2	18	7 5 E-3	3 E-3	13 30	1 50
acetone	78,518	16	28	9 6 E-1	1 0 E-1	22				
1,1-dichloroethene	1,469	111	139	1 8 E-2	9 0 E-3	5	6 0 E-1	1 E-2		
1,1-dichloroethane	19,329	62	77	2 4 E-1	1 0 E-1	6				
1,2-dichloroethene (total)	156,807	103	128	1 9 E+0	2 0 E-2	224				
chloroform	490,566	51	79	6 0 E+0	1 0 E-2	1,402	6 1 E-3	4 E-2		
1,2-dichloroethane	440,000	41	49	5 4 E+0			9 1 E-2	5 E-1		
carbon tetrachloride	55,001	175	219	6 7 E-1	7 0 E-4	2,245	1 3 E-1	9 E-2	4 00	0 16
trichloroethene	12,729	197	247	1 6 E-1			1 1 E-2	2 E-3		
1,1,2-trichloroethane	281	98	123	3 4 E-3	4 0 E-3	2	5 7 E-2	2 E-4	0 60	0 40
benzene	1,250	130	171	1 5 E-2			2 9 E-2	4 E-4		0 24
tetrachlororethene	14,810	533	667	1 8 E-1	1 0 E-2	42	5 1 E-2	9 E-3		2 00
arsenic	20	NA	NA	NA	3 0 E-4	NA	1 8 E+0	NA		
chromium	ND	NA	NA	NA	5 0 E-3	NA		NA	1 40	1 40

Total Pathway Risk =	3,970	8 E-1

Notes

(1) For exposure concentrations and intakes see Table 3-4 and Appendix B
(2) Based on modeling of selected chemicals and extrapolation for remaining chemicals
(3) Chronic Daily Intake (CDI) averaged over 70 year lifetime
(4) Noncancer Hazard Quotient = exposure level/reference dose Exposure level adjusted for exposure duration (30 yrs)
(5) Cancer Risk = Chronic Daily Intake (CDI) x Slope Factor
(6) HA = health advisory for drinking water

TABLE 5-4 (Cont.)

Calculated Risk for Groundwater Exposure South of New Hwy. 90 (Crosby Freeway)

Media: Air
Land Use Future
Exposed Population: Residential
Exposure Pathway: Inhalation of chemicals that have volatilized from groundwater during showering

Chemical Name	Exposure Concentration (1) mg/m3	Chronic Daily Intake (2) (mg/kg-day)	Inhalation RfC (mg/kg-day)	Noncancer Hazard Quotient (3)	Inhalation Unit Risk (m3/ug)	Inhalation Slope Factor (kg-day)/mg	Cancer Risk (4)
vinyl chloride	66	4 9 E-2			8 4 E-5	2 9 E-1	1 E-2
methylene chloride	300	2 2 E-1			4 7 E-7	1 6 E-3	4 E-4
acetone	80	5 9 E-2	3 0 E+0	0 05			
1,1-dichloroethene	12	9 1 E-3			5 0 E-5	1 8 E-1	2 E-3
1,1-dichloroethane	156	1 1 E-1					
1,2-dichloroethene (total)	1,292	9 5 E-1	5 0 E-1	4 40			
chloroform	3,586	2 6 E+0			2 3 E-5	8 1 E-2	2 E-1
1,2-dichloroethane	3,081	2 3 E+0			2 6 E-5	9 1 E-2	2 E-1
carbon tetrachloride	384	2 8 E-1			1 5 E-5	5 3 E-2	1 E-2
trichloroethene	94	6 9 E-2			4 8 E-6	1 7 E-2	1 E-3
1,1,2-trichloroethane	2 1	1 5 E-3			1 6 E-5	5 6 E-2	9 E-5
benzene	11	8 2 E-3			8 3 E-6	2 9 E-2	2 E-4
tetrachlororethene	100	7 4 E-2			9 4 E-7	3 3 E-3	2 E-4
arsenic	ND	NA			4 3 E-3	1 5 E+1	NA
chromium	ND	NA			1 2 E-2	4 2 E+1	NA
			Total Pathway Risk =	4 40			5 E-1

Notes

(1) For exposure concentrations and intakes see Table 3-4 and Appendix B
(2) Chronic Daily Intake (CDI) averaged over 70 year lifetime
(3) Noncancer Hazard Quotient = exposure level/reference dose Exposure level adjusted for exposure duration (30 yrs)
(4) Cancer Risk = Chronic Daily Intake (CDI) x Slope Factor

Total Ingestion and Inhalation Pathway Risk =	3,970	1 E+0

It should be noted that groundwater concentrations for the Riverdale exposure scenario are calculated in the INT unit only even though Riverdale wells are typically screened over a larger interval of the shallow alluvial deposits. Based on production well data from the French Limited site remedial system, the INT unit constitutes, at most, probably only 30% of the yield to these wells. Consequently, the risk calculated by ingestion of groundwater from wells tapping the INT unit is probably overestimated by at least 3 times.

The calculated future carcinogenic risks for the surface water exposure scenarios are shown in Tables 5-5 through 5-7 for the South Pond, East Pond and East Slough respectively. Again, these risks are calculated for future conditions assuming no remedial responses that contain or control DNAPL-impacted source area contributions to the groundwater. For the South Pond (Table 5-5), the calculated 10^{-6} excess cancer risk associated with ingestion during swimming is exceeded for vinyl chloride; methylene chloride; 1,1 dichloroethene; chloroform,.1,2-dichloroethane and tetrachloroethene (PCE). Dermal exposure during swimming also exceeds the calculated 10^{-6} excess cancer risk for these chemicals, as well as trichloroethene (TCE); 1,1,2-trichloroethane; and benzene. The carcinogenic risk associated with ingestion of contaminated fish from the South Pond only exceeds the 10^{-6} excess cancer risk criteria for vinyl chloride.

The calculated 10^{-6} excess cancer risk associated with ingestion during swimming in the East Pond (Table 5-6), are exceeded slightly for 1,2-dichloroethane; vinyl chloride and benzene. Dermal exposure during swimming slightly exceeds the calculated 10^{-6} excess cancer risk for these chemicals, as well as 1,1 DCE and chloroform. The carcinogenic risk associated with ingestion of contaminated fish from the East Pond slightly exceeds the 10^{-6} excess cancer risk criteria only for vinyl chloride.

The calculated 10^{-6} excess cancer risk associated with ingestion during swimming in the East Slough (Table 5-7), are exceeded for vinyl chloride; 1,1 DCE; 1,2-DCA, chloroform and benzene. Dermal exposure during swimming slightly exceeds the calculated 10^{-6} excess cancer risk for these same chemicals. The carcinogenic risk associated with ingestion of contaminated fish from the East Slough slightly exceeds the 10^{-6} excess cancer risk criteria for vinyl chloride; 1,2-dichloroethane, benzene and arsenic.

The relatively low risks associated with the surface water exposure scenarios reflect the very low calculated exposure concentrations and the relatively low intakes for each exposure pathway. It should be noted that the calculated surface water concentrations do not take into account the fact that most of the chemicals of concern would have a tendency to volatilize from the pond water, particularly near the water surface.

TABLE 5-5

Calculated Risk for South Pond Exposure Scenario

Media. Surface Water
Land Use Future
Exposed Population: Residential
Exposure Pathway. Ingestion of contaminated water while swimming

Chemical Name	Exposure Concentration (1) (ug/L)	Time for First Detection (2) (days)	Time for 95% of Max. (2) (days)	Chronic Daily Intake (3) (mg/kg-day)	Oral RfD (mg/kg-day)	Noncancer Hazard Quotient (4)	Oral Slope Factor (mg/kg-day)	Cancer Risk (5)
vinyl chloride	383	6	15	2 5 E-5			1 9 E+0	5 E-5
methylene chloride	2,294	2	5	1 5 E-4	6 0 E-2	0 006	7 5 E-3	1 E-6
acetone	4,002	1	3	2 6 E-4	1 0 E-1	0 006		
1,1-dichloroethene	60	8	17	3.9 E-6	9 0 E-3	0 001	6 0 E-1	2 E-6
1,1-dichloroethane	298	4	10	1.9 E-5	1 0 E-1	0 0005		
1,2-dichloroethene (total)	3,348	7	16	2.2 E-4	2 0 E-2	0 026		
chloroform	6,901	3	10	4 5 E-4	1 0 E-2	0 105	6 1 E-3	3 E-6
1,2-dichloroethane	1,053	3	6	6.9 E-5			9 1 E-2	6 E-6
carbon tetrachlonde	0 1	12	27	6 9 E-9	7 0 E-4	0 00002	1 3 E-1	9 E-10
trichloroethene	998	14	30	6 5 E-5			1 1 E-2	7 E-7
1,1,2-trichloroethane	29	7	15	1 9 E-6	4 0 E-3	0 001	5 7 E-2	1 E-7
benzene	68	9	21	4 5 E-6			2 9 E-2	1 E-7
tetrachlororethene	499	38	82	3 3 E-5	1 0 E-2	0 008	5 1 E-2	2 E-6
arsenic	2	10	21	1 4 E-7	3 0 E-4	0 001	1 8 E+0	2 E-7
chromium	ND	NA	NA	NA	5 0 E-3	NA		NA
Total Pathway Risk =						**0.15**		**6 E-5**

Notes

(1) For exposure concentrations and intakes see Table 3-4 and Appendix B
(2) Based on modeling of selected chemicals and extrapolation for remaining chemicals
(3) Chronic Daily Intake (CDI) assumes 0 05 L/hr intake for 2 6 hrs/day for 30 days/yr for 30 years for a 70 kg adult with a 70 year lifespan
(4) Noncancer Hazard Quotient = exposure level/reference dose Exposure level adjusted for exposure duration (30 yrs)
(5) Cancer Risk = Chronic Daily Intake (CDI) x Slope Factor

TABLE 5-5 (Cont.)

Calculated Risk for South Pond Exposure Scenario

Media: Surface Water
Land Use: Future
Exposed Population: Residential
Exposure Pathway: Dermal Contact with contaminated water while swimming

Chemical Name	Exposure Concentration (1) (ug/L)	Time for First Detection (2) (days)	Time for 95% of Max. (2) (days)	Absorbed Dose Rate (3) (mg/kg-day)	Oral RfD (mg/kg-day)	Noncancer Hazard Quotient (4)	Oral Slope Factor (mg/kg-day)	Cancer Risk (5)
vinyl chloride	383	6	15	7 0 E-5			1 9 E+0	1 E-4
methylene chloride	2,294	2	5	3 3 E-4	6 0 E-2	0 013	7 5 E-3	2 E-6
acetone	4,002	1	3	4 6 E-3	1 0 E-1	0 108		
1,1-dichloroethene	60	8	17	1 5 E-5	9 0 E-3	0 004	6 0 E-1	9 E-6
1,1-dichloroethane	298	4	10	3 5 E-4	1 0 E-1	0 0081		
1,2-dichloroethene (total)	3,348	7	16	3 6 E-3	2 0 E-2	0 423		
chloroform	6,901	3	10	5 2 E-3	1 0 E-2	1 206	6 1 E-3	3 E-5
1,2-dichloroethane	1,053	3	6	5 2 E-4			9 1 E-2	5 E-5
carbon tetrachloride	0 1	12	27	5 7 E-9	7 0 E-4	0 00002	1.3 E-1	7 E-10
trichloroethene	998	14	30	2 1 E-3			1 1 E-2	2 E-5
1,1,2-trichloroethane	29	7	15	7 3 E-5	4 0 E-3	0 042	5 7 E-2	4 E-6
benzene	68	9	21	7 4 E-5			2.9 E-2	2 E-6
tetrachlororethene	499	38	82	1 0 E-4	1 0 E-2	0 023	5 1 E-2	5 E-6
arsenic	2	10	21	1 7 E-8	3 0 E-4	0 000	1 8 E+0	3 E-8
chromium	ND	NA	NA	NA	5 0 E-3	NA		NA
					Total Pathway Risk =	1.83		3 E-4

Notes

(1) For exposure concentrations and intakes see Table 3-4 and Appendix B
(2) Based on modeling of selected chemicals and extrapolation for remaining chemicals
(3) Dermal contact adsorbed dose rate assumes swimming for 2 6 hrs/day for 30 days/yr for 30 years for a 70 kg adult with a 70 year lifespan
(4) Noncancer Hazard Quotient = exposure level/reference dose Exposure level adjusted for exposure duration (30 yrs)
(5) Cancer Risk = Adsorbed Dose Rate x Slope Factor

TABLE 5-5 (Cont.)

Calculated Risk for South Pond Exposure Scenario

Media: Fish and Aquatic Organisms
Land Use: Future
Exposed Population: Residential
Exposure Pathway: Ingestion of contaminated fish

Chemical Name	Exposure Concentration (1) (ug/kg)	Time for First Detection (2) (yrs)	Time for 95% of Max. (2) (yrs)	Chronic Daily Intake (3) (mg/kg-day)	Oral RfD (mg/kg-day)	Noncancer Hazard Quotient (4)	Oral Slope Factor (mg/kg-day)	Cancer Risk (5)
vinyl chloride	448	6	15	1 8 E-6			1 9 E+0	3 E-6
methylene chloride	11,468	2	5	4 6 E-5	6 0 E-2	0 002	7 5 E-3	3 E-7
acetone	4,002	1	3	1 6 E-5	1 0 E-1	0 0004		
1,1-dichloroethene	335	8	17	1 3 E-6	9 0 E-3	0 0003	6 0 E-1	8 E-7
1,1-dichloroethane	298	4	10	1 2 E-6	1 0 E-1	0 00003		
1,2-dichloroethene (total)	5,357	7	16	2 1 E-5	2 0 E-2	0 002		
chloroform	25,879	3	10	1 0 E-4	1 0 E-2	0 024	6 1 E-3	6 E-7
1,2-dichloroethane	1,263	3	6	5 0 E-6			9 1 E-2	5 E-7
carbon tetrachloride	2	12	27	8 0 E-9	7 0 E-4	0 00003	1 3 E-1	1 E-9
trichloroethene	10,575	14	30	4 2 E-5			1 1 E-2	5 E-7
1,1,2-trichloroethane	146	7	15	5 8 E-7	4 0 E-3	0 0003	5 7 E-2	3 E-8
benzene	356	9	21	1 4 E-6			2 9 E-2	4 E-8
tetrachlororethene	15,457	38	82	6 2 E-5	1 0 E-2	0 014	5 1 E-2	3 E-6
arsenic	93	10	21	3 7 E-7	3 0 E-4	0 003	1 8 E+0	6 E-7
chromium	ND	NA	NA	NA	5 0 E-3	NA		NA
					Total Pathway Risk =	0 05		1 E-5

Notes

(1) *For exposure concentrations and intakes see Table 3-4 and Appendix B*
(2) Based on modeling of selected chemicals and extrapolation for remaining chemicals
(3) Chronic Daily Intake (CDI) assumes ingestion of 949 gms of fish per year for 70 kg adult for 70 years and that 10% of fish consumed is from contaminated source
(4) Noncancer Hazard Quotient = exposure level/reference dose Exposure level adjusted for exposure duration (30 yrs)
(5) Cancer Risk = Adsorbed Dose Rate x Slope Factor

Total Ingestion and Dermal Adsorption Pathway Risk =	2 0	3 E-4

TABLE 5-6

Calculated Risk for East Pond Exposure Scenario

Media Surface Water
Land Use Future
Exposed Population Residential
Exposure Pathway Ingestion of contaminated water while swimming

Chemical Name	Exposure Concentration (1) (ug/L)	Time for First Detection (2) (days)	Time for 95% of Max. (2) (days)	Chronic Daily Intake (3) (mg/kg-day)	Oral RfD (mg/kg-day)	Noncancer Hazard Quotient (4)	Oral Slope Factor (mg/kg-day)	Cancer Risk (5)
vinyl chloride	366	1 3	3 9	2 4 E-5			1 9 E+0	5 E-5
methylene chloride	287	0 4	1 2	1 9 E-5	6 0 E-2	0 0007	7 5 E-3	1 E-7
acetone	8,741	0 3	0 9	5 7 E-4	1 0 E-1	0 01		
1,1-dichloroethene	14	1 5	4 3	8.9 E-7	9 0 E-3	0 0002	6 0 E-1	5 E-7
1,1-dichloroethane	255	0 8	2 4	1 7 E-5	1 0 E-1	0 0004		
1,2-dichloroethene (total)	523	1 4	4 0	3.4 E-5	2 0 E-2	0 0040		
chloroform	967	0 8	2 5	6.3 E-5	1 0 E-2	0 01	6 1 E-3	4 E-7
1,2-dichloroethane	1,725	0 6	1.5	1.1 E-4			9 1 E-2	1 E-5
carbon tetrachlonde	2 5	2 3	6 8	1 6 E-7	7 0 E-4	0 0005	1.3 E-1	2 E-8
trichloroethene	3	2 6	7 7	2.1 E-7			1.1 E-2	2 E-9
1,1,2-trichloroethane	ND	NA	NA	NA	4 0 E-3	NA	5 7 E-2	NA
benzene	993	1 5	5 3	6 5 E-5			2 9 E-2	2 E-6
tetrachlororethene	ND	NA	NA	NA	1 0 E-2	NA	5 1 E-2	NA
arsenic	3	1 8	5 3	1 7 E-7	3 0 E-4	0 001	1 8 E+0	3 E-7
chromium	11	1 8	5 3	7 4 E-7	5 0 E-3	0 0003		
				Total Pathway Risk =		0 04		6 E-5

Notes

(1) For exposure concentrations and intakes see Table 3-4 and Appendix B
(2) Based on modeling of selected chemicals and extrapolation for remaining chemicals
(3) Chronic Daily Intake (CDI) assumes 0 05 L/hr intake for 2 6 hrs/day for 30 days/yr for 30 years for a 70 kg adult with a 70 year lifespan
(4) Noncancer Hazard Quotient = exposure level/reference dose Exposure level adjusted for exposure duration (30 yrs)
(5) Cancer Risk = Chronic Daily Intake (CDI) x Slope Factor

TABLE 5-6 (Cont.)

Calculated Risk for East Pond Exposure Scenario

Media Surface Water
Land Use· Future
Exposed Population: Residential
Exposure Pathway Dermal Contact with contaminated water while swimming

Chemical Name	Exposure Concentration (1) (ug/L)	Time for First Detection (2) (days)	Time for 95% of Max. (2) (days)	Absorbed Dose Rate (3) (mg/kg-day)	Oral RfD (mg/kg-day)	Noncancer Hazard Quotient (4)	Oral Slope Factor (mg/kg-day)	Cancer Risk (5)
vinyl chloride	366	1 3	3 9	6 7 E-5			1 9 E+0	1 E-4
methylene chloride	287	0 4	1 2	4 1 E-5	6 0 E-2	0 002	7 5 E-3	3 E-7
acetone	8,741	0 3	0 9	1 0 E-2	1 0 E-1	0 24		
1,1-dichloroethene	14	1 5	4 3	3 3 E-6	9 0 E-3	0 0009	6 0 E-1	2 E-6
1,1-dichloroethane	255	0 8	2 4	3 0 E-4	1 0 E-1	0 007		
1,2-dichloroethene (total)	523	1 4	4 0	5 7 E-4	2 0 E-2	0 07		
chloroform	967	0 8	2 5	7 2 E-4	1 0 E-2	0 17	6 1 E-3	4 E-6
1,2-dichloroethane	1,725	0 6	1 5	8 5 E-4			9 1 E-2	8 E-5
carbon tetrachloride	2 5	2 3	6 8	1 3 E-7	7 0 E-4	0 0004	1 3 E-1	2 E-8
trichloroethene	3	2 6	7 7	6 6 E-6			1.1 E-2	7 E-8
1,1,2-trichloroethane	ND	NA	NA	NA	4 0 E-3	NA	5 7 E-2	NA
benzene	993	1 5	5 3	1 1 E-3			2 9 E-2	3 E-5
tetrachlororethene	ND	NA	NA	NA	1 0 E-2	NA	5 1 E-2	NA
arsenic	3	1 8	5 3	2 1 E-8	3 0 E-4	0 0002	1 8 E+0	4 E-8
chromium	11	1 8	5 3	9 0 E-8	5 0 E-3	0 00004		
					Total Pathway Risk =	0 48		2 E-4

Notes

(1) For exposure concentrations and intakes see Table 3-4 and Appendix B
(2) Based on modeling of selected chemicals and extrapolation for remaining chemicals
(3) Dermal contact adsorbed dose rate assumes swimming for 2 6 hrs/day for 30 days/yr for 30 years for a 70 kg adult with a 70 year lifespan
(4) Noncancer Hazard Quotient = exposure level/reference dose Exposure level adjusted for exposure duration (30 yrs)
(5) Cancer Risk = Adsorbed Dose Rate x Slope Factor

TABLE 5-6 (Cont.)

Calculated Risk for East Pond Exposure Scenario

Media: Fish and Aquatic Organisms
Land Use. Future
Exposed Population: Residential
Exposure Pathway Ingestion of contaminated fish

Chemical Name	Exposure Concentration (1) (ug/kg)	Time for First Detection (2) (yrs)	Time for 95% of Max. (2) (yrs)	Chronic Daily Intake (3) (mg/kg-day)	Oral RfD (mg/kg-day)	Noncancer Hazard Quotient (4)	Oral Slope Factor (mg/kg-day)	Cancer Risk (5)
vinyl chloride	428	1 3	3 9	1 7 E-6			1 9 E+0	3 E-6
methylene chloride	1,437	0 4	1 2	5 7 E-6	6 0 E-2	0 0002	7 5 E-3	4 E-8
acetone	8,741	0 3	0 9	3 5 E-5	1 0 E-1	0 0008		
1,1-dichloroethene	76	1 5	4 3	3 0 E-7	9 0 E-3	0 0001	6 0 E-1	2 E-7
1,1-dichloroethane	255	0 8	2 4	1 0 E-6	1 0 E-1	0 00002		
1,2-dichloroethene (total)	836	1 4	4 0	3 3 E-6	2 0 E-2	0 0004		
chloroform	3,626	0 8	2 5	1 4 E-5	1 0 E-2	0 003	6 1 E-3	9 E-8
1,2-dichloroethane	2,070	0 6	1 5	8 2 E-6			9 1 E-2	7 E-7
carbon tetrachlonde	47	2 3	6 8	1 9 E-7	7 0 E-4	0 0006	1 3 E-1	2 E-8
trichloroethene	33	2 6	7 7	1 3 E-7			1 1 E-2	1 E-9
1,1,2-trichloroethane	ND	NA	NA	NA	4 0 E-3	NA	5 7 E-2	NA
benzene	5,164	1 5	5 3	2 1 E-5			2 9 E-2	6 E-7
tetrachlororethene	ND	NA	NA	NA	1 0 E-2	NA	5 1 E-2	NA
arsenic	115	1 8	5 3	4 6 E-7	3 0 E-4	0 004	1 8 E+0	8 E-7
chromium	2,248	1 8	5 3	8 9 E-6	5 0 E-3	0 004		
					Total Pathway Risk =	0 01		6 E-6

Notes

(1) For exposure concentrations and intakes see Table 3-4 and Appendix B
(2) Based on modeling of selected chemicals and extrapolation for remaining chemicals
(3) Chronic Daily Intake (CDI) assumes ingestion of 949 gms of fish per year for 70 kg adult for 70 years and that 10% of fish consumed is from contaminated source
(4) Noncancer Hazard Quotient = exposure level/reference dose Exposure level adjusted for exposure duration (30 yrs)
(5) Cancer Risk = Adsorbed Dose Rate x Slope Factor

Total Ingestion and Dermal Adsorption Pathway Risk =	0 53	3 E-4

TABLE 5-7

Calculated Risk for East Slough Exposure Scenario

Media Surface Water
Land Use Future
Exposed Population: Residential
Exposure Pathway Ingestion of contaminated water while swimming

Chemical Name	Exposure Concentration (1) (ug/L)	Time for First Detection (2) (days)	Time for 95% of Max (2) (days)	Chronic Daily Intake (3) (mg/kg-day)	Oral RfD (mg/kg-day)	Noncancer Hazard Quotient (4)	Oral Slope Factor (mg/kg-day)	Cancer Risk (5)
vinyl chloride	1,022	30 0	151 5	6 7 E-5			1 9 E+0	1 E-4
methylene chloride	803	9 4	48 3	5 3 E-5	6 0 E-2	0 002	7 5 E-3	4 E-7
acetone	24,413	4 0	34 1	1 6 E-3	1 0 E-1	0 04		
1,1-dichloroethene	38	32 7	168 6	2 5 E-6	9 0 E-3	0 0006	6 0 E-1	1 E-6
1,1-dichloroethane	711	18 2	93 6	4 7 E-5	1 0 E-1	0 001		
1,2-dichloroethene (total)	1,460	30 2	155 7	9 6 E-5	2 0 E-2	0 01		
chloroform	2,701	17 0	95 8	1.8 E-4	1 0 E-2	0 04	6 1 E-3	1 E-6
1,2-dichloroethane	4,818	13 0	59 4	3 2 E-4			9 1 E-2	3 E-5
carbon tetrachloride	6 9	51 4	264 9	4.5 E-7	7 0 E-4	0 002	1 3 E-1	6 E-8
trichloroethene	9	58 0	299 2	5 7 E-7			1 1 E-2	6 E-9
1,1,2-trichloroethane	ND	NA	NA	NA	4 0 E-3	NA	5 7 E-2	NA
benzene	2,774	35 0	207 1	1 8 E-4			2 9 E-2	5 E-6
tetrachlororethene	ND	NA	NA	NA	1 0 E-2	NA	5 1 E-2	NA
arsenic	7	40 2	207 1	4.8 E-7	3 0 E-4	0 004	1 8 E+0	8 E-7
chromium	31	40 2	207 1	2 1 E-6	5 0 E-3	0 001		
Total Pathway Risk =						**0 10**		**2 E-4**

Notes

(1) For exposure concentrations and intakes see Table 3-4 and Appendix B
(2) Based on modeling of selected chemicals and extrapolation for remaining chemicals
(3) Chronic Daily Intake (CDI) assumes 0 05 L/hr intake for 2 6 hrs/day for 30 days/yr for 30 years for a 70 kg adult with a 70 year lifespan
(4) Noncancer Hazard Quotient = exposure level/reference dose Exposure level adjusted for exposure duration (30 yrs)
(5) Cancer Risk = Chronic Daily Intake (CDI) x Slope Factor

TABLE 5-7 (Cont.)

Calculated Risk for East Slough Exposure Scenario

Media. Surface Water
Land Use Future
Exposed Population: Residential
Exposure Pathway. Dermal Contact with contaminated water while swimming

Chemical Name	Exposure Concentration (1) (ug/L)	Time for First Detection (2) (days)	Time for 95% of Max (2) (days)	Absorbed Dose Rate (3) (mg/kg-day)	Oral RfD (mg/kg-day)	Noncancer Hazard Quotient (4)	Oral Slope Factor (mg/kg-day)	Cancer Risk (5)
vinyl chloride	1,022	30 0	151 5	1 9 E-4			1 9 E+0	4 E-4
methylene chloride	803	9 4	48 3	1 1 E-4	6 0 E-2	0 004	7 5 E-3	9 E-7
acetone	24,413	4 0	34 1	2 8 E-2	1 0 E-1	0 66		
1,1-dichloroethene	38	32 7	168 6	9 2 E-6	9 0 E-3	0 002	6 0 E-1	5 E-6
1,1-dichloroethane	711	18 2	93 6	8 2 E-4	1 0 E-1	0 02		
1,2-dichloroethene (total)	1,460	30 2	155 7	1 6 E-3	2 0 E-2	0 18		
chloroform	2,701	17 0	95 8	2 0 E-3	1 0 E-2	0 47	6 1 E-3	1 E-5
1,2-dichloroethane	4,818	13 0	59 4	2 4 E-3			9 1 E-2	2 E-4
carbon tetrachloride	6 9	51 4	264 9	3.8 E-7	7 0 E-4	0 001	1 3 E-1	5 E-8
trichloroethene	9	58 0	299 2	1 8 E-5			1 1 E-2	2 E-7
1,1,2-trichloroethane	ND	NA	NA	NA	4 0 E-3	NA	5 7 E-2	NA
benzene	2,774	35 0	207 1	3 0 E-3			2 9 E-2	9 E-5
tetrachlororethene	ND	NA	NA	NA	1 0 E-2	NA	5 1 E-2	NA
arsenic	7	40 2	207 1	5 9 E-8	3 0 E-4	0 0005	1 8 E+0	1 E-7
chromium	31	40 2	207 1	2 5 E-7	5 0 E-3	0 0001		
					Total Pathway Risk =	1 35		7 E-4

Notes

(1) For exposure concentrations and intakes see Table 3-4 and Appendix B
(2) Based on modeling of selected chemicals and extrapolation for remaining chemicals
(3) Dermal contact adsorbed dose rate assumes swimming for 2 6 hrs/day for 30 days/yr for 30 years for a 70 kg adult with a 70 year lifespan
(4) Noncancer Hazard Quotient = exposure level/reference dose Exposure level adjusted for exposure duration (30 yrs)
(5) Cancer Risk = Adsorbed Dose Rate x Slope Factor

TABLE 5-7 (Cont.)

Calculated Risk for East Slough Exposure Scenario

Media: Fish and Aquatic Organisms
Land Use: Future
Exposed Population: Residential
Exposure Pathway. Ingestion of contaminated fish

Chemical Name	Exposure Concentration (1) (ug/kg)	Time for First Detection (2) (days)	Time for 95% of Max. (2) (days)	Chronic Daily Intake (3) (mg/kg-day)	Oral RfD (mg/kg-day)	Noncancer Hazard Quotient (4)	Oral Slope Factor (mg/kg-day)	Cancer Risk (5)
vinyl chloride	1,196	30 0	151 5	4 76E-06			1 9 E+0	9 E-6
methylene chloride	4,015	9 4	48 3	1 60E-05	6 0 E-2	0 0006	7 5 E-3	1 E-7
acetone	24,413	4 0	34 1	9 72E-05	1 0 E-1	0 002		
1,1-dichloroethene	213	32 7	168 8	8 46E-07	9 0 E-3	0 0002	6 0 E-1	5 E-7
1,1-dichloroethane	711	18 2	93 6	2 83E-06	1 0 E-1	0 0001		
1,2-dichloroethene (total)	2,336	30 2	155 7	9 30E-06	2 0 E-2	0 001		
chloroform	10,129	17 0	95 8	4 03E-05	1 0 E-2	0 009	6 1 E-3	2 E-7
1,2-dichloroethane	5,782	13 0	59 4	2 30E-05			9 1 E-2	2 E-6
carbon tetrachloride	132	51 4	264 9	5 24E-07	7 0 E-4	0 002	1 3 E-1	7 E-8
trichloroethene	93	58 0	299 2	3 70E-07			1 1 E-2	4 E-9
1,1,2-trichloroethane	ND	NA	NA	NA	4 0 E-3	NA	5 7 E-2	NA
benzene	14,425	35 0	207 1	5 74E-05			2 9 E-2	2 E-6
tetrachlororethene	ND	NA	NA	NA	1 0 E-2	NA	5 1 E-2	NA
arsenic	321	40 2	207 1	1 28E-06	3 0 E-4	0 01	1 8 E+0	2 E-6
chromium	6,278	40 2	207 1	2 50E-05	5 0 E-3	0 01		
					Total Pathway Risk =	0 03		2 E-5

Notes

(1) For exposure concentrations and intakes see Table 3-4 and Appendix B
(2) Based on modeling of selected chemicals and extrapolation for remaining chemicals
(3) Chronic Daily Intake (CDI) assumes ingestion of 949 gms of fish per year for 70 kg adult for 70 years and that 10% of fish consumed is from contaminated source
(4) Noncancer Hazard Quotient = exposure level/reference dose Exposure level adjusted for exposure duration (30 yrs)
(5) Cancer Risk = Adsorbed Dose Rate x Slope Factor

Total Ingestion and Dermal Adsorption Pathway Risk =	1 4700	9 E-4

Non-carcinogenic Effects

The potential for non-carcinogenic effects is evaluated by comparing an exposure level over a specified time period with a reference dose derived for a similar exposure period. This ratio of exposure to toxicity is called a hazard quotient and is described as follows:

Noncancer Hazard Quotient

Noncancer Hazard Quotient = E/RfD

where:

E = exposure level (or intake);

RfD = reference dose; and

E and RfD are expressed in the same units and represent the same exposure period (i.e., chronic, subchronic, or shorter-term).

The noncancer hazard quotient assumes that there is a level of exposure (i.e., RfD) below which it is unlikely for even sensitive populations to experience adverse health effects. If the exposure level (E) exceeds this threshold (i.e., E/RfD exceeds unity), there may be concern for potential noncancer effects. As a rule, the greater the value of E/RfD above unity, the greater the level of concern. It is important to emphasize that the level of concern does not increase linearly as the RfD is approached or exceeded because RfDs do not have equal accuracy or precision and are not based on the same severity of toxic effects. Thus, the slopes of the dose-response curve in excess of the RfD can range widely depending on the substance.

Three exposure durations are considered for the possibility of adverse noncarcinogenic health effects: chronic, subchronic, and shorter-term exposures.

Chronic exposures for humans are considered to range in duration from seven years to a lifetime. Chronic long-term exposures are applicable for inhabitants of nearby residences and year-round users of specified drinking water sources such as the Riverdale Subdivision residents.

Subchronic human exposures are considered to range in duration from two weeks to seven years and are applicable, for example, to children that might attend a junior high school near the site for no more than two or three years. For this risk evaluation at the French Limited site there are no exposure pathways that are applicable for this type of exposure so that subchronic exposures are not assessed.

Exposures less than two weeks in duration are considered only for identified chemicals known to be developmental toxicants. In the case of these types of chemicals, short-term exposures of as little as a day or two can be of concern. The chemicals of concern in this risk evaluation that meet this criteria are assessed by comparing exposure concentrations with one-day and ten-day health advisories. These health advisories only apply to risks associated with drinking water ingestion.

The results of applying the non-cancer hazard quotient equation to the future exposure scenarios developed for the DNAPL-impacted areas of the French Limited site are summarized in Tables 5-1 through 5-7. It can be seen that, in the absence of remedial responses that contain or control DNAPL-impacted source area contributions to the groundwater, there is a potential future risk associated with exposures to contaminated groundwater in drinking water supply wells in the receptor locations identified in this risk evaluation. These risks are summarized for the receptor locations north of Gulf Pump Road in Tables 5-1 and 5-2, for the Riverdale Subdivision in Table 5-3 and south of the New Highway 90 in Table 5-4.

Most of the chemicals of concern that have a listed oral reference dose (RfD) have calculated future concentrations in groundwater in these receptor locations that result in a calculated hazard quotient greater than unity for drinking water ingestion under the RME scenario. Arsenic and chromium were not detected in the source areas for these pathways and so do not have a calculated future risk. For the receptor location north of Gulf Pump Road near the INT-11 area (Table 5-1), all organic chemicals of concern, except 1,1,2 TCA, have calculated hazard quotients exceeding unity for the drinking water ingestion scenario. For the receptor location north of Gulf Pump Road near the S1-13 area (Table 5-2), the calculated hazard quotient for all organic chemicals of concern, except carbon tetrachloride, exceeded unity. At the Riverdale receptor location (Table 5-3), the calculated hazard quotient exceeded unity for four organic chemicals of concern, acetone, 1,2 DCE (total), carbon tetrachloride and 1,1,2 TCA. At the new Highway 90 location (Table 5-4), the calculated hazard quotient for all organic chemicals of concern exceeded unity.

Only two chemicals of concern, acetone and 1,2 DCE (total), have reported RfD values for inhalation. For the inhalation during showering scenario at all four receptor locations for the groundwater pathways, the calculated hazard quotient for these two chemicals did not exceed unity.

It should be noted that groundwater concentrations for the Riverdale exposure scenarios are calculated in the INT unit only even though Riverdale wells are typically screened over a larger interval of the shallow alluvial deposits. Based on production well data from the French Limited site, the INT unit has relatively low permeability, and typically yields less than 30% of the shallower S1 unit sands. Consequently, the risk calculated by ingestion of groundwater from wells tapping the INT unit is overestimated by at least 3 times.

The calculated noncarcinogenic risks for the surface water exposure scenarios (Tables 5-5 through 5-7) are negligible due to the very low calculated exposure concentrations and the relatively low intakes associated with these exposure scenarios. Only one constituent, chloroform, has a calculated hazard quotient that slightly exceeds unity for dermal exposure during swimming in the South Pond (Table 5-5).

Short-term Exposure Risks

In addition to the chronic exposure risks associated with the chemicals of concern, short term exposure risks were evaluated by comparison of exposure concentrations with one-day and ten-day health advisories for drinking water. The calculated future concentrations of methylene chloride and carbon tetrachloride exceed both the one-day and the ten-day health advisories at all locations except Riverdale. The calculated future concentrations of 1,1,2 TCA exceeds the ten-day health advisories north of Gulf Pump Road near S1-13 (Table 5-2) and at Riverdale (Table 5-3). The calculated future concentrations of benzene exceeds the ten-day health advisory at all four locations while that of PCE exceeds the ten-day health advisory at all locations except Riverdale.

5.1.2 Aggregate Risks for Multiple Substances

For the overall risk associated with DNAPL-impacted areas of the French Limited site, the potential health effects of more than one chemical (both carcinogens and other toxicants) were assessed. Estimating risk or hazard potential by considering one chemical at a time might significantly underestimate the risks associated with simultaneous exposures to several substances. The methodology to assess the overall potential for cancer and noncancer effects posed by multiple chemicals, follows EPA (1986b) *Guidelines for the Health Risk Assessment of Chemical Mixtures* that can also be applied to the case of simultaneous exposures to several chemicals from a variety of sources by more than one exposure pathway. Although the calculation procedures differ for carcinogenic and noncarcinogenic effects, both sets of procedures assume dose additivity in the absence of information on specific mixtures.

Carcinogenic Effects

The aggregate cancer risk equation for multiple substances is described as follows:

Cancer Risk Equation for Multiple Substances

$$Risk_T = \Sigma Risk_i$$

where:

$Risk_T$ = the total cancer risk, expressed as a unitless probability; and

$Risk_i$ = the risk estimate for the i^{th} chemical.

This equation was used to estimate the incremental individual lifetime cancer risk for simultaneous exposure to several carcinogens and is based on EPA's (1986 a,b) risk assessment guidelines. This equation represents an approximation of the precise equation for combining risks, which accounts for the joint probabilities of the same individual developing cancer as a consequence of exposure to two or more carcinogens.

The risk summation technique assumes that intakes of individual substances are small. It also assumes independence of action by the compounds involved (i.e., that there are no synergistic or antagonistic chemical interactions) and that all chemicals produce the same effect (i.e., cancer). The results of this summation are included in Tables 5-1 through 5-7. It is evident that, in the absence of remedial responses that contain or control DNAPL-impacted source area contributions to groundwater, the potential future risk associated with cumulative exposures to several constituents in contaminated groundwater at all four receptor locations evaluated significantly exceeds the 10^{-6} excess cancer risk criteria for ingestion under the Reasonable Maximum Exposure (RME) scenario

Again, it should be noted that the aggregate risk calculations for the Riverdale area are performed only for the INT unit which constitutes probably only 30% of the yield to Riverdale domestic wells. Consequently, the risk calculated by ingestion of groundwater from wells tapping the INT unit is overestimated by at least 3 times. However, even with this consideration, the potential future risk would significantly exceed the 10^{-6} excess cancer risk criteria.

The calculated aggregate carcinogenic risk for multiple substances for the surface water exposure scenarios (Tables 5-3 through 5-5) are relatively low, but do exceed the 10^{-6} excess cancer risk criteria for all pathways. The highest aggregate risk is for swimming in the East Slough, where ingestion is calculated to have an aggregate excess cancer risk of 2×10^{-4}, and dermal contact during swimming, an aggregate excess cancer risk of 7×10^{-4}.

Noncarcinogenic Effects

To assess the overall potential for noncarcinogenic effects posed by more than one chemical, a hazard index (HI) approach was used that is based on EPA's (1986b) *Guidelines for Health Risk Assessment of Chemical Mixtures*. This approach assumes that simultaneous sub-threshold exposures to several chemicals could result in an adverse health effect. It also assumes that the magnitude of the adverse effect is proportional to the sum of the ratios of the sub-threshold exposures to acceptable exposures. The hazard index is equal to the sum of the hazard quotients, described as follows:

Noncancer Hazard Index

$$\text{Hazard Index} = \Sigma E_i/RfD_i$$

where:

E_i = exposure level (or intake) for the i^{th} chemical;

RfD_i = reference dose for the i^{th} chemical

E and RfD are expressed in the same units and represent the same exposure period (i.e., chronic, subchronic, or shorter-term).

In this equation, E and RfD represent the same exposure period (e.g., subchronic, chronic, or shorter-term). When the hazard index exceeds unity, there may be concern for potential health effects. While any single chemical with an exposure level greater than the toxicity value will cause the hazard index to exceed unity, for multiple chemical exposures, the hazard index can also exceed unity even if no single chemical exposure exceeds its RfD. If this occurs, the chemicals may be segregated by similar effect or target organ to determine the potential health risks Separate hazard indexes may be derived for each effect, if any exceed one.

The results of the summation of risk for potential future exposure to non-carcinogenic constituents are included in Tables 5-1 through 5-7. It is evident that, in the absence of remedial responses that contain or control DNAPL-impacted area contributions to groundwater, the potential future risk associated with cumulative exposures to all chemicals-of-concern by ingestion of contaminated groundwater significantly exceeds the hazard index criteria for ingestion under the Reasonable Maximum Exposure (RME) scenario at all four receptor locations evaluated. The noncarcinogenic cumulative risk for the inhalation during showering scenario did not exceed the hazard index criteria of one at any of the four receptor locations.

The calculated aggregate noncarcinogenic risks for the surface water exposure scenarios (Tables 5-5 through 5-7) are very low due to the very low calculated exposure concentrations and the relatively low intake volumes associated with this exposure scenario. The hazard index criteria of one is exceeded for dermal exposure during swimming scenario in the South Pond (Table 5-5) and the East Slough (Table 5-7).

5.1.3 Combination of Risks Across Exposure Pathways

This section describes the methodology that was used for combining the multi-chemical risk estimates across exposure pathways when such aggregation is appropriate. These calculations are performed for instances where an individual might be exposed to a substance or combination of substances through several pathways. For example a resident of the Riverdale Subdivision may be potentially exposed through drinking contaminated groundwater and by eating contaminated fish from an effected pond. The total exposure to various chemicals will equal the sum of the exposures by all pathways. However, the risks from all exposure pathways evaluated for a site are not necessarily summed.

There are two steps required to determine whether risks or hazard indices for two or more pathways should be combined for a single exposed individual or group of individuals. The first is to identify reasonable exposure pathway combinations. If two pathways do not affect the same individual or subpopulation, neither pathway's individual risk estimate or hazard index affects the other, and risks should not be combined. The second is to examine whether it is likely that the same individuals would consistently face the "reasonable maximum exposure" (RME) by more than one pathway. If the key RME assumptions for more than one pathway apply to the same individual or subpopulation, then the RME risks for more than one pathway are combined.

The results of the exposure assessment and individual pathway risk assessment, summarized in Tables 5-1 through 5-7, indicate that exposure by ingestion and inhalation of chemicals in potentially contaminated groundwater poses the most significant risk to the public health. The surface water pathways pose such a comparatively low potential risk that summing risks and hazard indices across pathways essentially yields the same risks as that posed by the groundwater pathway.

5.2 Ecological Risk Characterization

The ecological risk characterization is similar to the human risk characterization, in that exposure assumptions and toxicological data are combined with site data to estimate risk. In the absence of quantitative values or other data useful for a quantitative risk assessment, the ecological risk assessment may necessarily be restricted to a qualitative discussion of the pathways by which environmental receptors may be exposed to potential risks, and how these risks might affect individuals of a species, total populations, and the ecosystem as a whole.

Given the nature of DNAPL-impacted areas at the French Limited site and the results of the exposure assessment discussed in Section 3.0 of this report, the only potentially significant ecological risk assessment pathway is aquatic life in surface ponds and sloughs that may receive affected groundwater discharge.

By direct comparison between the available ambient water quality criteria (AWQC) and surface water concentrations, the potential hazards to fish and other aquatic life can be readily evaluated for many chemicals. In this comparison, acute criteria for short-term exposure can be compared with the maximum surface water concentrations, and chronic criteria can be compared with the average surface water concentrations, usually calculated as the geometric mean of the samples under consideration. The exposure analysis results presented in Section 3.0 indicated that potential surface water concentrations of contaminants of concern resulting from discharge of contaminated groundwater are generally far below concentrations likely to have any effect on aquatic biota (Table 4-3 in Section 4.0). The only exceedences of Aquatic Chronic and Aquatic Acute concentration criteria are for calculated future concentrations of chloroform in the South Pond and East Slough.

5.3 Discussion of Uncertainties

All risk assessments involve the use of assumptions, judgment, and imperfect data to varying degrees. This results in uncertainty in the final estimates of risk. The uncertainties affecting risk estimates are discussed in the remainder of this section.

Uncertainty in a risk assessment may arise from many sources including:

- Environmental chemistry sampling and analysis;
- Misidentification or failure to be all-inclusive in hazard identification;
- Choice of models and input parameters in exposure assessment and fate and transport modeling;
- Choice of models or evaluation of toxicological data in dose-response quantification; and
- Assumptions concerning exposure scenarios and population distributions.

Uncertainty may be magnified in the assessment through a combination of these sources.

In risk assessments in which considerable uncertainty is anticipated, a technique commonly employed to compensate for uncertainty is to bias the assessment in the direction of overestimation of risk. This is often termed a "worst case" or "conservative" analysis. The net effect of combining numerous conservative assumptions is that the final estimates of risk may be greatly overestimated.

In this risk evaluation, the concept of Reasonable Maximum Exposure (RME) was followed (EPA, 1989c). The estimates of exposure concentration described in Section 3.0, present a significant area of uncertainty. However, the parameter values selected for the exposure assessment calculations yield the maximum exposures that can be reasonably expected to occur. This is because the values of the most significant parameters that influence constituent transport in groundwater were selected very conservatively as described in Section 3.8. Consequently the calculated intake concentrations and the resulting risks are probably much higher than the average, but within the realm of reasonable assumptions

The absence of environmental parameter measurements also contributes to uncertainty. Lack of site-specific measurements requires that estimates must be based on literature values, regression equations, extrapolations, and/or best professional judgment. Modeling errors can stem from a lack of validation or verification of the models. Typically an order of magnitude result is considered to be satisfactory for most complex modeling scenarios.

Environmental chemistry sampling and analysis error can stem from the error inherent in the procedures, from a failure to take an adequate number of samples to arrive at sufficient area resolution, from mistakes on the part of the sampler, or from the heterogeneity of the matrix being sampled. One of the most effective ways of minimizing procedural or systematic error is to subject the data to a strict quality control review. This was the case with the French Limited site DNAPL data which was subject to a rigorous quality assurance project plan (QAPP). Even with all data rigorously quality assured, however, there is still error inherent in all analytical procedures, and it is still not possible to definitively determine if any given sample is truly representative of site conditions.

In almost all risk assessments, the largest source of uncertainty is in critical toxicity values (RfDs and cancer slope factors), and these uncertainties may significantly affect the magnitude of the risk estimates presented in a risk evaluation. Health criteria for evaluating long-term exposures such as RfDs or cancer slope factors are based on concepts and assumptions which bias an evaluation in the direction of overestimation of health risk. The EPA noted in its Guidelines for Carcinogenic Risk Assessment (EPA 1986b):

> *There are major uncertainties in extrapolating both from animals to humans and from high to low doses. There are important species differences in uptake, metabolism, and organ distribution of carcinogens, as well as species and strain differences in target site susceptibility. Human populations are variable with respect to geometric constitution, diet, occupational and home environment, activity patterns, and other cultural factors.*

These uncertainties are compensated for by using upper bounds for cancer potency factors for carcinogens and safety factors for reference doses for noncarcinogens.

At best, the assumptions used in this risk evaluation provide a rough but reasonable estimate of the upper limit of risk, i.e., it is not likely that the true risk would be much more than the estimated risk, but it could very well be considerably lower, even approaching zero.

5.4 Conclusion

The assumptions used in this EA provide a reasonable estimate of the upper limit of risk associated with DNAPL-impacted areas at the French Limited site. The risk evaluation process provides a method for evaluating the need for additional remedial action and for the comparison of remedial alternatives.

The comparison of risks associated with various exposure routes indicates that, in the absence of remedial action for the DNAPL-impacted areas, there is an unacceptably high short-term future risk (i.e. within 1 to 2 years) associated with groundwater ingestion at hypothetical exposure points north of Gulf Pump Road near the INT-11 and S1-13 DNAPL areas (Tables 5-1 and 5-2). These exposure points were chosen for risk evaluation because they are adjacent to the highest groundwater concentrations associated with DNAPL-impacted areas. While groundwater concentrations in the S1-16 and INT-West potential source areas are significantly lower than that in the S1-13 and INT-11 areas, it is evident that hypothetical exposure points north of Gulf Pump Road adjacent to the S1-16 and INT-West areas would also produce unacceptably high short-term risks if these source concentrations are not reduced or controlled.

The nearby Riverdale residential area has a long-term (i.e. 10 to 50 years) future risk associated with potentially affected groundwater exposure from domestic wells (Table 5-3). This results from the ability of DNAPL-impacted soils to provide continuing sources of chemicals to the groundwater. The migration of this affected groundwater to nearby domestic wells is possible if hydraulic gradients are established in the direction of these receptor locations. Similarly, domestic wells south of the New Hwy. 90 may also be potentially affected in the long-term (i.e. 30 to 200 years) if DNAPL-impacted source areas are not remediated or controlled.

The results of the Risk Evaluation indicate that an appropriate remedial response is to control migration of DNAPL-impacted groundwater to possible receptor locations. The present remedial operations at French Limited prevent off-site migration of affected groundwater by controlling hydraulic gradients in the shallow alluvial zone. Long-term migration control of DNAPL-impacted groundwater may be achieved by maintaining hydraulic controls and/or by isolating potential DNAPL-impacted soil areas from active groundwater flow regimes.

The INT-11 area is the only area where DNAPL has actually been confirmed to exist outside the sheetpile cutoff wall (AHA, 1993). Given the acknowledged technical limitations to eliminating DNAPL occurrence[1], the Risk Evaluation results indicate that containment and/or control of the INT-11 DNAPL source area will be necessary in order to eliminate unacceptable potential future risks at an exposure point north of Gulf Pump Road. If current remedial operations are suspended, the calculated future risk associated with this area is short-term in nature (Table 5-1). Accordingly, remedial options associated with this source area should be implemented as soon as practicable.

[1] U S EPA May, 1992 Considerations in Ground Water Remediation at Superfund Sites and RCRA Facilities Update (PB92-963358)

The other defined potential DNAPL-impacted source areas, S1-13, S1-16 and INT-West, do not have confirmed DNAPL presence outside the sheetpile cutoff wall. Accordingly, enhanced remedial activities, that have been implemented in these areas in early 1994, have a reasonable opportunity to reduced source concentrations to the point where their contribution to groundwater is sufficiently low that unacceptable risks are not seen at the first potential point of exposure. Monitoring of remedial progress over the next one or two years will establish whether additional containment/control measures are required in these source areas. If current remedial operations are suspended, the calculated future risk associated with these areas are short-term in nature, due to the proximity of the areas to the point of first potential exposure. Accordingly, if additional remedial measures are determined to be required, they should be implemented as soon as practicable.

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BOOKMARK

APPENDIX A

SOLUTE TRANSPORT MODEL ASSUMPTIONS, INPUT PARAMETERS, AND RESULTS

Introduction

As part of the Risk Evaluation process, several potential future exposure scenarios were developed. These are described in Chapter 3.0 of this report Solute transport modeling was used to evaluate downgradient concentrations of five indicator chemical compounds at specified exposure points for each of these scenarios. The advective transport of dissolved acetone, benzene, vinyl chloride, 1,2 DCA, and chloroform was simulated for five pathways in the S1 unit and three pathways in the INT unit. These compounds were selected for modeling to represent the bulk of the chemicals of concern. The five compounds are among the most prevalent compounds in French limited groundwater and cover the range of groundwater mobility, with Koc values of 2.2 to 83, as listed in Table 3-2 The location of the eight pathways are depicted in Figure 3-2. For each of the five compounds, up to five simulations were run to determine the time at which concentrations in excess of their standard analytical detection limits (5 micrograms per liter) would reach projected downgradient receptors

Method

The computer model AT123D is a analytical transient one-, two-, and three-dimensional computer code used to simulate the movement of contaminants in an aquifer system. The program was developed by G T Yeh in conjunction with Oak Ridge National Laboratory and the U. S. Department of Energy (DOE). The model is capable of simulating radioactive, solute, and heat transport with instantaneous, continuous, or finite duration releases. Mechanisms of transport that may be included in analyses are advection, hydrodynamic dispersion, adsorption, decay, and losses due to volatilization. Boundary conditions that may be simulated include Dirichlet, Neumann, mixed type (Cauchy), or radiation boundaries.

Model Input

The most significant factors governing contaminant transport are groundwater gradients, the hydraulic conductivity, and the degree of chemical sorption (which retards the transport of solutes compared to that of groundwater flow) Each modeling run was performed using the highest possible groundwater gradients with measured hydraulic conductivity values This yields the highest advective transport

of constituents in groundwater which is appropriate for evaluation of the Reasonable Maximum Exposure (RME). Average hydraulic conductivity for the S1 and INT units were determined from 51 pumping and recovery tests performed on S1 and INT wells.

Retardation factors for each chemical were calculated by the AT123D model, from the standard retardation equation (Freeze & Cherry, 1979).

$$R = 1 + (\rho_b/n) * Kd$$

where:

R = the retardation factor,
ρ_b = the bulk density of the media,
n = the porosity of the media, and
Kd = the distribution coefficient of the chemical

The variables ρ_b, n, and Kd are entered as model input and the source of each is explained below. Porosities and bulk densities of the S1 unit (0 25 and 1.82 g/cc respectively) and INT unit (0.20 and 1.70 g/cc respectively) were obtained from the Remediation Design Report (ENSR, 1991; Vol II, Appendix E). Because bulk density and porosity are considered to be constants for a given media, the distribution coefficient, Kd, is the input parameter that most affects chemical retardation. The Kd for each chemical is therefore a critical input parameter of the model.

The distribution coefficient is a measure of the tendency of a chemical compound to partition between soil and water at equilibrium conditions It can be defined as

$$Kd = C_S/C_W$$

where, C_S is the concentration in soil (mass/mass) and C_W is the concentration in water (mass/volume) soil Kd has the units of volume/mass

Distribution coefficients were calculated for 1,2 DCA and chloroform from soil and groundwater concentrations obtained in the INT unit from the DNAPL Study Field Data Report (AHA, 1993). Soil sampling during the DNAPL study was generally biased towards high contaminant concentrations by the presence of high organic vapor monitor (OVM) readings during the field screening of cores To obtain *effective* soil concentrations over the length of a monitoring well filterpack, concentrations from samples were applied only to the sample interval and concentrations of zero were applied to the remainder of the filterpack. This, in effect, integrates intervals of high and low concentrations of contaminated soil over the length of the filterpack, just as a groundwater samples from the well do This

resulting soil concentration was then divided by the groundwater concentration from the well to obtain the Kd.

Distribution coefficients for acetone, benzene and vinyl chloride were determined indirectly because representative soil concentrations were not available due to high detection limits. These Kd values were calculated from a derived fraction of organic carbon (f_{OC}) in soil obtained from 1,2 DCA and chloroform Kd values by the relationship:

$$Kd = f_{OC} \times K_{OC}$$

where, Kd and f_{OC} have been previously defined. K_{OC} is the theoretical partitioning of a compound between a substrate of pure organic carbon and water at equilibrium. K_{OC} values are readily available from various compilations of physical and chemical data for organic compounds. Values used in this report were obtained from the EPA, 1986, Superfund Public Health Evaluation Manual (EPA/540/1-86/60) and are summarized in Table A-1 for the chemicals modeled.

The calculated fraction of organic carbon (0.01) was assumed to be equal for both the S1 and INT units based upon values given in the Remediation Design Report (ENSR, 1991; Vol. II, Appendix E) Similarly, due to a lack of sufficient field data, Kd values for each compound were assumed to be equal for the S1 and INT units Because the derived Kd values used data from the INT unit, the calculated Kd value for the S1 is probably high.

Retardation of solute transport due to adsorption by natural organic matter was determined by the model from conservative estimates of each distribution coefficient (Kd). The relative retardation values, from highest to lowest retardation, are benzene, vinyl chloride, chloroform, 1,2-DCA, and acetone with retardation values of 7.0, 5.2, 3.6, 3 0, and 1.2 respectively in the S1 unit, and 8 1, 5 8, 4 1, 3 3, and 1.2 respectively, in the INT unit.

All simulations were conducted for one-dimensional flow with finite longitudinal dispersion and negligible transverse and vertical dispersion (AT123D requires non-zero values for these parameters). Groundwater velocities and chemical fluxes were calculated independently from site specific data and used to determine chemical release rates for model input. For each chemical, the maximum observed groundwater concentration in each source area was used to calculate the chemical release rate. These "local" maximum concentration values used to calculate model input values are shown in Table 2-3 and were obtained from a database search of analytical data from the wells listed for each area.

Chemical transport was modeled conservatively and each simulation represents a Reasonable Maximum Exposure (RME) Constant chemical release rates were maintained for the duration of each simulation to represent the presence of a

continuing contaminant source due to the presence of DNAPL. Hydraulic gradients were selected to be conservatively large relative to current conditions. This assumption represents possible future conditions under which groundwater flow is influenced by an operation such as continuous quarry dewatering, groundwater pumping or drought.

Longitudinal dispersivities were chosen from literature values for comparable geologic media (NUREG/CR-3066,1982). The ratio of S1 to INT longitudinal dispersivities were based upon the values given in the Remediation Design Report (ENSR, 1991; Vol. II, Appendix E). The actual values from this report were not used because of the small scale of the tracer test from which the values were derived. While biological removal of contaminants strongly affects chemical concentrations under the current groundwater remediation system, biological and other types of decay were not included in these simulations for the sake of conservatism.

Individual Model Simulations and Modeling Results

Aquifer parameters such as hydraulic conductivity, porosity hydraulic gradient, and groundwater velocity were held constant for each modeled area. In all model simulations, the relative arrival time of the compounds at a given downgradient location was controlled primarily by chemical retardation. This order of appearance was consistent; acetone, 1,2 DCA, chloroform, vinyl chloride, then benzene regardless of relative initial concentration

<u>INT Unit</u>

Three scenarios were developed for contaminant transport in the INT unit for acetone, benzene, vinyl chloride, 1,2 DCA, and chloroform In each case, a relatively large hydraulic gradient (0.040 or 0.0176) was selected to reflect possible future conditions of continuous groundwater pumping or quarry de-watering south or southwest of the French Ltd. site. The 0.040 gradient used in the simulations of a domestic well north of Gulf Pump Road was calculated between ambient groundwater levels and approximate water levels in INT pumping wells The 0.0176 gradient used in the simulation of INT transport to the new highway 90 and the Riverdale Subdivision was calculated between ambient groundwater levels at the southwest end of French Lagoon and the most recent sand quarrying operation south of the Riverdale Subdivision and assumed that groundwater would be drawn down to the base of the S1 unit. While this gradient is unrealistically large for current conditions, this scenario is consistent with the most Reasonable Maximum Exposure (RME) concept used for this Risk Evaluation The current contaminant distribution in the INT strongly suggest that such a quarry de-watering may have provided a significant driving force for contaminant movement in the past While this configuration may not develop a hydraulic gradient from the INT-11 area

directly to the south, the magnitude of the gradient is believed to be the maximum likely.

Chemical Transport From INT-11 Area South to New U.S. Highway 90

The chemical transport of the five compounds from the INT-11 area south to new U.S. Highway 90 was conducted to project the exposure of possible future receptors if development were to occur to the south and is depicted as pathway 1 in Figure 3-2. Acetone is projected to arrive first in 17 years, then 1,2-DCA in 45 years, chloroform next in 55 years, then vinyl chloride in 90 years, and benzene in 140 years (Table A-3 and Figures A-1, A-2, A-3, A-4 and A-5).

As the figures show, without remediation efforts to contain or remove the contaminant sources at the INT-11 area, the potential for exposure at this receptor location is significant if a sufficient hydraulic gradient is imposed in this direction In such a situation, there would be the possibility of exposure for future developments south of U.S Highway 90 in as little as 17 years.

Chemical Transport From the Southwest End of French Lagoon Southwest to the Riverdale Subdivision

The chemical transport of the five compounds from the southwest end of French Lagoon (termed the INT-West Area) to the southwest was modeled to project the potential future exposure of residents in the Riverdale Subdivision and is depicted as pathway 2 in Figure 3-2. The model assumed a future high hydraulic gradient in the direction of Riverdale imposed by a dewatering operation This is consistent with the concept of a RME used in this Risk Evaluation

The relative mobility (retardation) of the four compounds controls the arrival time to the Riverdale Subdivision more than their initial concentrations. The high initial concentration and low sorption characteristics of acetone insure that it will be the first compound to reach Riverdale (at 9.2 ppb in 8 years) under the imposed conditions 1,2-DCA follows in 10 years, then vinyl chloride and chloroform in 16 years, and finally benzene in 24 years (Table A-4 and Figures A-6, A-7, A-8, A-9 and A-10).

Unlike the other areas used in the modeling runs, the modeling of contaminant transport towards the Riverdale Subdivision can be readily compared to the current contaminant distribution. Only within the last year has this area received enhanced remedial attention. Though this plume is now hydraulically contained, the extent of contaminants in this area have not been significantly reduced by the remediation system. A source of contaminants has been present in the west end of the lagoon since about 1967 when disposal at French Ltd began. The source was not

contained by the sheetpile wall until 1989. Sand quarrying operations with dewatering operated as recently as 1989 south of Riverdale. Given the heterogeneity of the INT, the variability of contaminant concentrations near the lagoon and the variability of direction and magnitude of hydraulic gradients that may have occurred over the last twenty years, the modeling results are consistent with the presence of the lobate contaminant plume in the INT which currently extends from the west end of the French Lagoon to the southwest.

Without remedial intervention, the possibility of a future increase in size or capacity of the groundwater wellfield in the Riverdale Subdivision could worsen the problem by local increases of the hydraulic gradient. Currently, the French Limited Groundwater Remediation System hydraulically contains the affected areas and prevents any migration of affected groundwater towards Riverdale.

Chemical Transport From the INT-11 Area South to a Hypothetical Domestic Well North of Gulf Pump Road

A simulation was conducted to represent the closest possible future receptor to contaminated INT groundwater. This simulation included the movement of the five modeled chemicals in groundwater from the INT-11 source area to a hypothetical domestic well on the north side of Gulf Pump Road The exposure pathway is depicted in Figure 3-2 as pathway 3. The high concentrations in this area and large imposed hydraulic gradients used in the model, have resulted in virtually immediate arrival of all of the modeled compounds The results are shown in Table A-9 and Figures A-31, A-32, A-33, A-34, and A-35.

S1 Unit

Five simulations of contaminant transport in the S1 unit were conducted to estimate the movement of the five compounds from S1 source areas to three surface water bodies and two pathways of direct ingestion of contaminated groundwater from the S1 unit. The human uptake of contaminated water, either as groundwater or surface water, dermal contact with surface water, and consumption of aquatic organisms are the proposed routes of exposure in these simulations

The two direct pathways are represented by simulations of contaminated groundwater flow to hypothetical wells north of Gulf Pump Road and north of the new highway 90.

The three simulations of groundwater transport to surface water bodies were conducted with hydraulic gradients of 2 feet over the distances between the sources and proposed receptors (a slough or pond). This results in gradients of, 0 025 between the S1-16 area and the East Slough, 0 0083 between the S1-16

area and the East Pond and 0.0042 between the S1-13 area and the South Pond. These gradients are believed to be the maximum likely to develop during periods of extended drought. Since the ponds act as recharge areas after precipitation events, the discharge gradients were assumed to operate for 10% of the time

As with the INT simulations, the model predicted the arrival of the five compounds to the proposed points of exposure in the S1 unit in the same order (of increasing mobility or decreasing retardation); acetone, 1,2 DCA, chloroform, vinyl chloride, and benzene.

S1-16 Area to East Slough

Of the three S1/surface water unit simulations, the chemical transport between the S1-16 area and the East Slough was conducted with the largest hydraulic gradient (due to the short distance of 80 feet between the source area and the slough). This potential groundwater exposure pathway is depicted as pathway 4 in Figure 3-2 This scenario represents the shortest travel times of the three S1/surface water simulations between a contaminant source and a receptor. The modeling results indicate that acetone will arrive first in 5 days, 1,2-DCA next in 14 days, followed by chloroform in 18 days, then vinyl chloride and benzene in 5 weeks (Table A-5 and Figures A-11, A-12, A-13, A-14, and A-15).

S1-16 Area to East Pond

The potential groundwater exposure pathway between the S1-16 area and the East pond is depicted as pathway 5 in Figure 3-2. Due to the greater distance between the contaminant source and the exposure point, the gradient between the S1-16 area and the East pond is less than to the East Slough. Similarly the arrival times are also greater. The modeling results of the chemical transport between the S1-16 area and the East Pond indicate that acetone will arrive first in 3 months, then 1,2-DCA in 8 months, followed by chloroform in 10 months, then vinyl chloride in 16 months, and benzene in 20 months (Table A-6 and Figures A-16, A-17, A-18, A-19, and A-20).

S1-13 Area
to South Pond

Groundwater flow between the S1-13 area to the South Pond represents the longest travel time of the three S1/surface water model simulations and is depicted as pathway 7 in Figure 3-2. Acetone will arrive in 1.1 years, 1,2-DCA will arrive in 3.2 years, chloroform next in 3.4 years, then vinyl chloride in 6 years, and benzene in 9.5 years (Table A-7 and Figures A-21, A-22, A-23, A-24, and A-25).

The large volume of the South Pond provides the greatest dilution of the three ponds and results in the lowest mixed concentrations for vinyl chloride, 1,2 DCA, and chloroform (Table A-2)

Direct Exposure Pathways in the S1 unit

Two simulations were conducted of groundwater transport from the S1-13 area to hypothetical domestic wells north of Gulf Pump Road and north of the new highway 90.

Chemical Transport From S1-13 Area South to New U.S Highway 90

With the exception of benzene, concentrations of the five modeled compounds in the S1-13 area represent the highest documented in the areas of known or suspected occurrence of DNAPL in the S1 unit This area was therefore chosen for modeling simulations to represent the RME in the S1 unit

The chemical transport of the five compounds from the S1-13 area south to new U.S. Highway 90 was conducted to project the exposure of possible future receptors if development were to occur to the south and is depicted as pathway 6 in Figure 3-2. Acetone is projected to arrive first in 12 months, then 1,2-DCA in 32 months, chloroform next in 35 months, then vinyl chloride in 41 months, and benzene in 7.5 years (Table A-8 and Figures A-26, A-27, A-28, A-29 and A-30).

As the figures show, without remediation efforts to contain or remove the contaminant sources at the S1-13 area, the potential for exposure at this receptor location is significant if a sufficient hydraulic gradient is imposed in this direction In such a situation, there would be the possibility of exposure for future developments south of U.S. Highway 90 in as little as 2 to 3 years

Chemical Transport From the S1-13 Area South to a Hypothetical Domestic Well North of Gulf Pump Road

A simulation was conducted to represent the closest possible future receptor to contaminated S1 groundwater from the area of the greatest contaminant concentrations. This simulation included the movement of the five modeled chemicals in groundwater from the S1-13 source area to a hypothetical domestic well between the south boundary of the French Limited property and the north side of Gulf Pump Road The exposure pathway is depicted in Figure 3-2 as pathway 8 The high concentrations in this area and large imposed hydraulic gradients used in the model, have resulted in virtually immediate arrival of all of the modeled compounds. the results are shown in Table A-10 and Figures A-36, A-37, A-38, A-39, and A-40.

Conclusions

The time to reach down gradient receptors depends primarily upon groundwater velocity (which is in tern a function of hydraulic conductivity and hydraulic gradient), distance, chemical retardation and to a lesser degree hydrodynamic dispersion. At French Ltd., the magnitude and direction of hydraulic gradients are the physical parameters most likely to change and have a major effect upon the groundwater flow system. For a given set of aquifer parameters, the time required for a contaminant to reach a downgradient receptors depends most upon the chemical retardation of the chemical compound.

The results of the modeling and independent calculations indicate that, due to dilution effects in surface water, groundwater contamination is of greater concern than contamination in ponds and sloughs.

Of the S1 scenarios of groundwater discharge to surface water, the transport to the East Slough poses the worst case, with 1,2 DCA and benzene arriving above 5 ppb in 2 and 5 weeks, respectively The short distance between the source and the slough also resulted in highest contaminant loading rates for vinyl chloride, 1,2 DCA and chloroform and highest mixed surface water concentrations for all of the four compounds (due to the smallest dilution volume). Groundwater flow between the S1-13 area to the South Pond represents the longest travel time, with 1,2 DCA and benzene arriving above 5 ppb in 1.2 years and 9.5 years, respectively. This scenario also represented the largest contaminant dilution and, with the exception of benzene, the lowest resulting mixed surface water concentrations.

Without continued remedial action and under conditions of extreme hydraulic gradients, contaminated groundwater in both the INT and S1 units is likely to be extensive. Within the next 100 years non-potable groundwater could extend west to Riverdale, south to the new U.S. Highway 90, and east and southeast to East Slough and East Pond.

Because to modeling runs rely heavily on hydraulic conductivity, gradients, and distribution coefficients, a slight change in any of these values can greatly effect contaminant movement rates. Because of these shortcomings, the modeling runs should not be interpreted as fact, but as interpretive tools in estimating contaminant movement.

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Table A-1: Input Values for Modeling

AREA	GW Velocity (m/hr)	Porosity	Acetone		Benzene		Vinyl Chloride		1,2-DCA		Chloroform	
			GW max (ug/L)	Q (kg/hr)	GW max (ug/L)	Q (kg/hr)	GW max (ug/L)	Q (kg/hr)	GW max (ug/L)	Q (kg/hr)	GW max (ug/L)	Q (kg/hr)
INT-11 Hwy 90	2.12E-03	0.20	81,000	3.43E-05	1,200	5.08E-07	6,000	2.54E-06	860,000	3.64E-04	850,000	3.60E-04
INT-11 Wells	4.80E-03	0.20	81,000	7.78E-05	1,200	1.15E-06	6,000	5.76E-06	860,000	8.26E-04	850,000	8.16E-04
INT-West	2.12E-03	0.20	110,000	4 66E-05	3,600	1.52E-06	16,000	6.78E-06	8,700	3.68E-06	250	1.06E-07
S1-13 Hwy 90	2.40E-02	0.25	76,036	4.56E-04	1,300	7.80E-06	7,278	4.37E-05	20,000	1.20E-04	131,131	7.87E-04
S1-16 E Slough	3.40E-02	0.25	33,443	2.84E-04	3,800	3.23E-05	1,400	1.19E-05	6,600	5.61E-05	3,700	3.15E-05
S1-16 E. Pond	1.13E-02	0.25	33,443	9.48E-05	3,800	1.08E-05	1,400	3.97E-06	6,600	1.87E-05	3,700	1.05E-05
S1-13 Wells	5.44E-02	0.25	76,036	1.03E-03	1,300	1.77E-05	7,278	9.90E-05	20,000	2.72E-04	131,131	1.78E-03
S1-13 S. Pond	5.73E-03	0 25	76,036	1.09E-04	1,300	1.86E-06	7,278	1.04E-05	20,000	2.86E-05	131,131	1.88E-04

GW = groundwater

max = maximum concentration detected

DCA = dichloroethane

Q = constant waste release rate (number required in AT123D)

Notes

All maximum groundwater concentrations taken from monitoring data from wells outside the sheet pile wall

Table A-1 (cont.) Input Values for Modeling

AREA	GW Elev. Change (ft)	Total Distance (ft)	Hydraulic Gradient	Hydraulic Conductivity (cm/s)	Hydraulic Conductivity (m/hr)	Effective Porosity	GW Velocity (m/hr)
INT-11 Hwy 90	30	1,700	0.0176	6.60E-04	0.024	0.20	2.12E-03
INT-11 Wells	10	250	0.0400	6.60E-04	0.024	0.20	4.80E-03
INT-West	30	1,700	0.0176	6.60E-04	0.024	0.20	2.12E-03
S1-13 Hwy 90	30	1,700	0.0176	9.50E-03	0.340	0.25	2.40E-02
S1-16 E. Slough	2	80	0.0250	9.50E-03	0 340	0.25	3.40E-02
S1-16 E. Pond	2	240	0.0083	9 50E-03	0 340	0.25	1 13E-02
S1-13 Wells	10	250	0.0400	9 50E-03	0.340	0.25	5 44E-02
S1-13 S. Pond	2	475	0.0042	9 50E-03	0.340	0.25	5.73E-03

Table A-1 (cont.) Input Values for Modeling

AREA	Kd in m3/kg					Bulk Density (4) (g/cc)	Lateral Dispersivity (5) (m)	Longitudinal Dispersivity (6) (m)
	Acetone (2)	Benzene (2)	Vinyl Chl (2)	1,2-DCA (1)	Chloroform (1)			
INT-Unit	2 20E-05	8.30E-04	5.70E-04	2.70E-04	3.60E-04	1.70	1.00E-05	5
S1-Unit	2.20E-05	8.30E-04	5.70E-04	2.70E-04	3.60E-04	1.82	1.00E-05	8

Notes

Kd = chemical partitioning between soil or sediment and water at equilibrium

foc = fraction of organic carbon in the soil matrix

Koc = chemical partitioning between organic carbon and water at equilibrium

(1) Kd for 1,2-DCA and Chloroform based on soil and groundwater data from INT-123

- INT-123 and INT-127 had the best data for Kd calculations based on sample coverage
- Final numbers were based on INT-123 because it provided more conservative Kd's
- Actual soil concentrations were applied over the sample interval only
- A soil concentration of zero was applied to intervals were the well filter pack existed but no samples were taken

(2) Kd's for acetone, benzene and vinyl chloride were calculated using a foc derived from the 1,2-DCA and chloroform Kd's

- Using Kd = foc x Koc
- Calculated foc = 0 01 was then used to calculate benzene and vinyl chloride Kd's
- Acetone Koc = 2 2 (L/kg) - Benzene Koc = 83 (L/kg) - 1,2-DCA Koc = 14 (L/kg)
- Vinyl chloride Koc = 57 (L/kg) - Chloroform Koc = 31 (L/kg)

(3) Kd for S1 unit assumed to be the same as the INT unit (sufficient field data not available)

- Similar foc values for the S1 and INT units based on values given in the ENSR remediation design report (ENSR, 1991)

(4) Bulk densities from ENSR design report (ENSR, 1991)

(5) Very low value for lateral dispersivity assumed for conservative one-dimensional transport

(6) INT value based on literature Ratio of INT/S1 values based on ENSR design report (ENSR, 1991)

Table A-2: Calculations for Groundwater Discharge to Surrounding Surface Water Bodies

Acetone

AREA	Discharge Area (m2)	Flux (m3/day)	Conc. (ug/L)	Loading (kg/day)	Loading (kg/yr)	Water Volume (m3)	Mixed Conc. (ug/l)
S1-13 to South Pond	900	3.1	76,036	0.236	86.0	43,500	3,956
S1-16 to East Pond	432	2.9	33,443	0.097	35.4	8,100	8,741
S1-16 to East Slough	244	5.0	33,443	0.167	61.0	5,000	24,413

Benzene

AREA	Discharge Area (m2)	Flux (m3/day)	Conc. (ug/L)	Loading (kg/day)	Loading (kg/yr)	Water Volume (m3)	Mixed Conc. (ug/l)
S1-13 to South Pond	900	3 1	1,300	0.004	1.5	43,500	68
S1-16 to East Pond	432	2.9	3,800	0.011	4.0	8,100	993
S1-16 to East Slough	244	5.0	3,800	0 019	6.9	5,000	2,774

Mixed concentrations assume a 2 yr time period of loading into the same water volume with complete mixing

Hydraulic gradient from source area to surface water body assumed to be prevailing 10% of the time

(Note that groundwater only discharges to ponds during periods of low precipitation and high evaporation)

Table A-2 (cont.): Calculations for Groundwater Discharge to Surrounding Surface Water Bodies

Vinyl Chloride

AREA	Discharge Area (m2)	Flux (m3/day)	Conc. (ug/L)	Loading (kg/day)	Loading (kg/yr)	Water Volume (m3)	Mixed Conc. (ug/l)
S1-13 to South Pond	900	3.1	7,278	0.023	8.2	43,500	379
S1-16 to East Pond	432	2.9	1,400	0.004	1.5	8,100	366
S1-16 to East Slough	244	5.0	1,400	0.007	2.6	5,000	1,022

1,2-DCA

AREA	Discharge Area (m2)	Flux (m3/day)	Conc. (ug/L)	Loading (kg/day)	Loading (kg/yr)	Water Volume (m3)	Mixed Conc. (ug/l)
S1-13 to South Pond	900	3 1	20,000	0 062	22 6	43,500	1,040
S1-16 to East Pond	432	2 9	6,600	0 019	7 0	8,100	1,725
S1-16 to East Slough	244	5 0	6,600	0 033	12 0	5,000	4,818

Mixed concentrations assume a 2 yr time period of loading into the same water volume with complete mixing

Hydraulic gradient from source area to surface water body assumed to be prevailing 10% of the time

(Note that groundwater only discharges to ponds during periods of low precipitation and high evaporation)

Table A-2 (cont.): Calculations for Groundwater Discharge to Surrounding Surface Water Bodies

Chloroform

AREA	Discharge Area (m2)	Flux (m3/day)	Conc. (ug/L)	Loading (kg/day)	Loading (kg/yr)	Water Volume (m3)	Mixed Conc. (ug/l)
S1-13 to South Pond	900	3.1	131,131	0.407	148.4	43,500	6,822
S1-16 to East Pond	432	2.9	3,700	0 011	3.9	8,100	967
S1-16 to East Slough	244	5.0	3,700	0.019	6.8	5,000	2,701

Mixed concentrations assume a 2 yr time period of loading into the same water volume with complete mixing

Hydraulic gradient from source area to surface water body assumed to be prevailing 10% of the time

(Note that groundwater only discharges to ponds during periods of low precipitation and high evaporation)

Table A-3: Transport in the INT Unit From INT-11 Area to New Hwy 90

Distance to highway = 450 m

All concentrations in ppb

Acetone (criteria = 3,500 ppb) Time to highway = 16-17 yrs

Time	Distance						
	m	0	100	200	300	400	450
	ft.	0	328	656	984	1312	1476
7 yrs.		81000	45300	182	0	0	0
10 yrs		81000	73100	9150	8 4	0	0
17 yrs.		81000	81000	71400	18400	297	10 8

Benzene (criteria = 5 ppb) Time to highway = 130-140 yrs

Time	Distance						
	m	0	100	200	300	400	450
	ft.	0	328	656	984	1312	1476
50 yrs.		1200	730	5.77	0	0	0
100 yrs.		1200	1180	831	73	1 9	0
140 yrs.		1200	1190	1160	736	88 3	12 1

Vinyl Chloride (criteria = 2 ppb) Time to highway = 80-90 yrs

Time	Distance						
	m	0	100	200	300	400	450
	ft.	0	328	656	984	1312	1476
30 yrs.		6000	2260	2 7	0	0	0
50 yrs.		6000	5400	739	1 25	0	0
90 yrs.		6000	5930	5590	2180	81	5 4

1,2 DCA (criteria = 5 ppb) Time to highway = 40-45 yrs

Time	Distance						
	m	0	100	200	300	400	450
	ft.	0	328	656	984	1312	1476
20 yrs.		860000	529000	3540	0	0	0
40 yrs.		860000	872000	576000	41300	89	1
45 yrs.		860000	845000	718000	134000	1270	36 1

Chloroform (criteria = 100 ppb) Time to highway = 50-55 yrs

Time	Distance						
	m	0	100	200	300	400	450
	ft.	0	328	656	984	1312	1476
20 yrs.		850000	289000	144	0	0	0
50 yrs.		850000	849000	587000	48100	114	1 35
55 yrs		850000	845000	700000	124000	1020	25 8

Figure A-1
Acetone Transport in the INT
From INT-11 Area to New Hwy 90

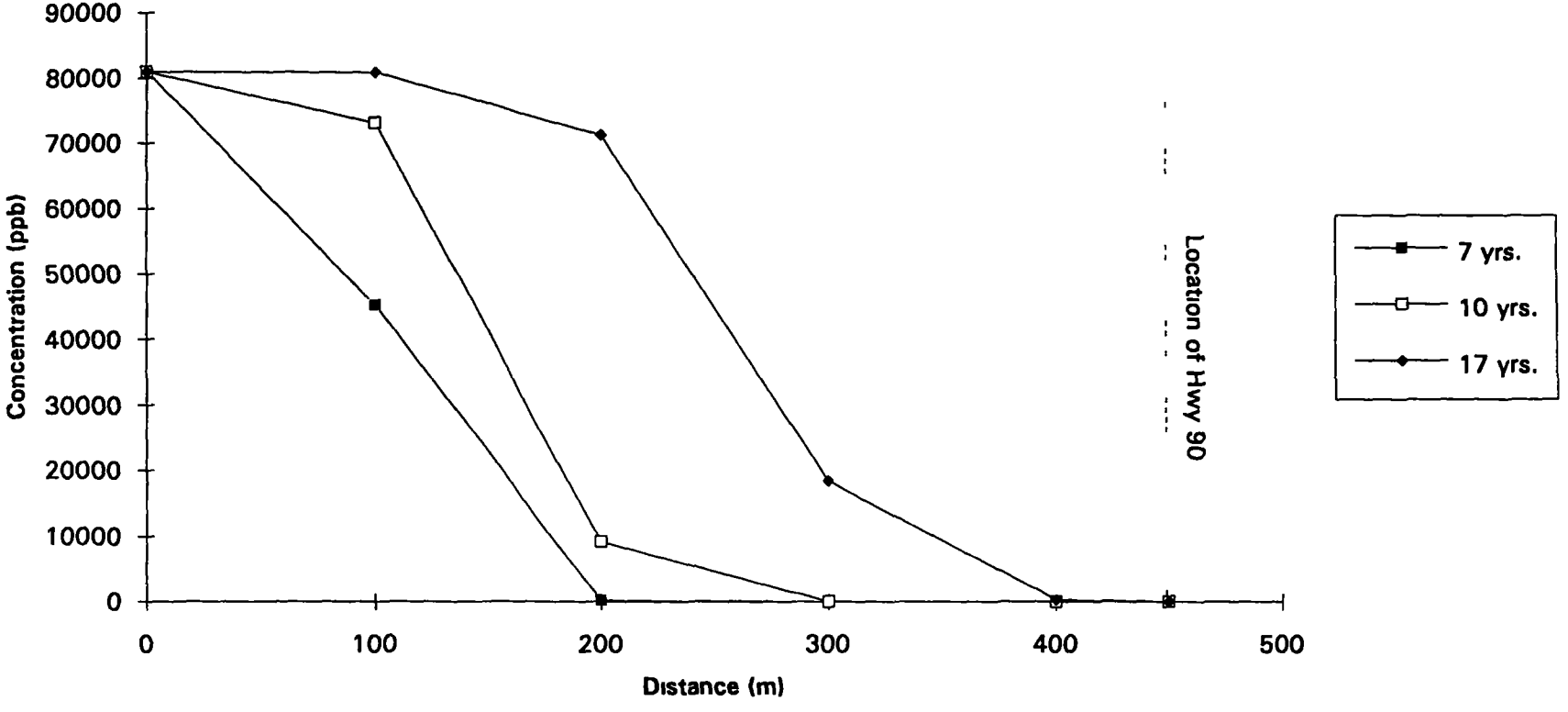

Figure A-2
Benzene Transport in the INT
From INT-11 Area to New Hwy 90

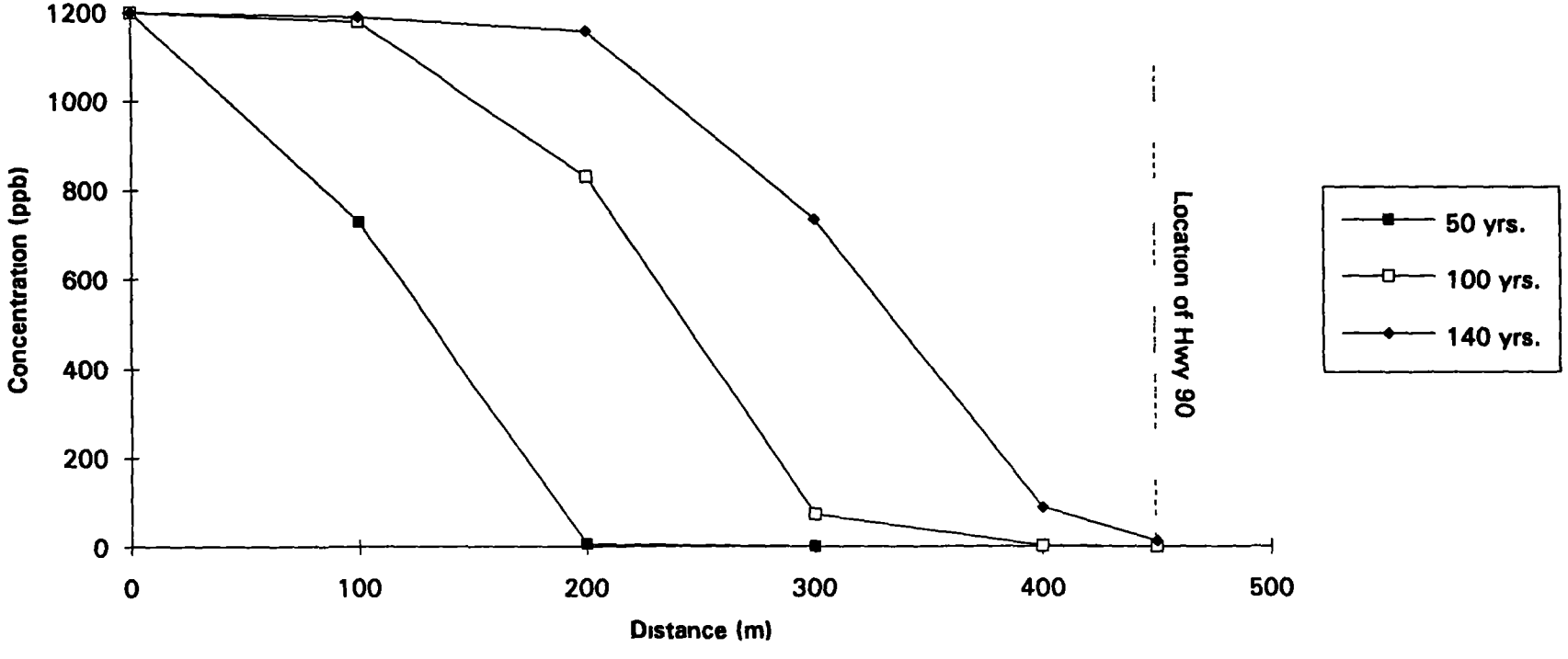

Figure A-3
Vinyl Chloride Transport in the INT
From INT-11 Area to New Hwy 90

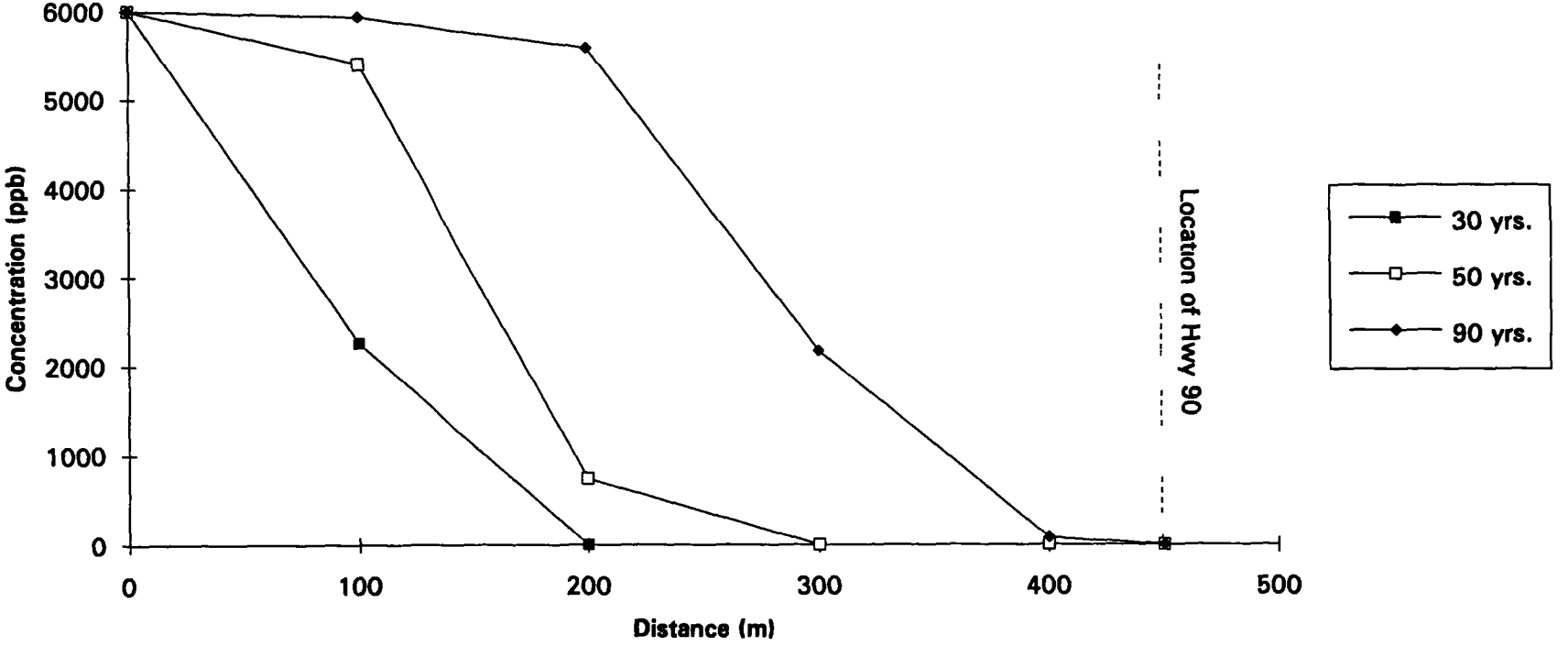

Figure A-4
1,2 DCA Transport in the INT
From INT-11 Area to New Hwy 90

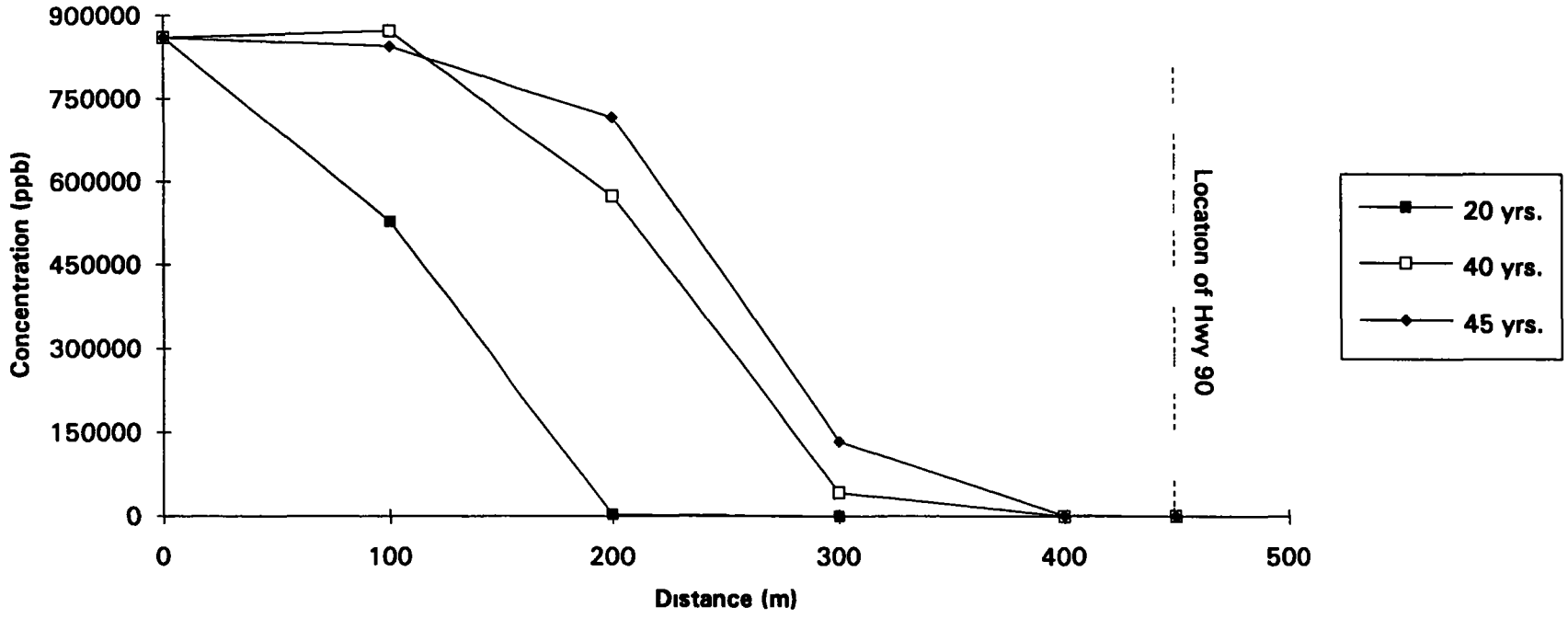

Figure A-5
Chloroform Transport in the INT
From INT-11 Area to New Hwy 90

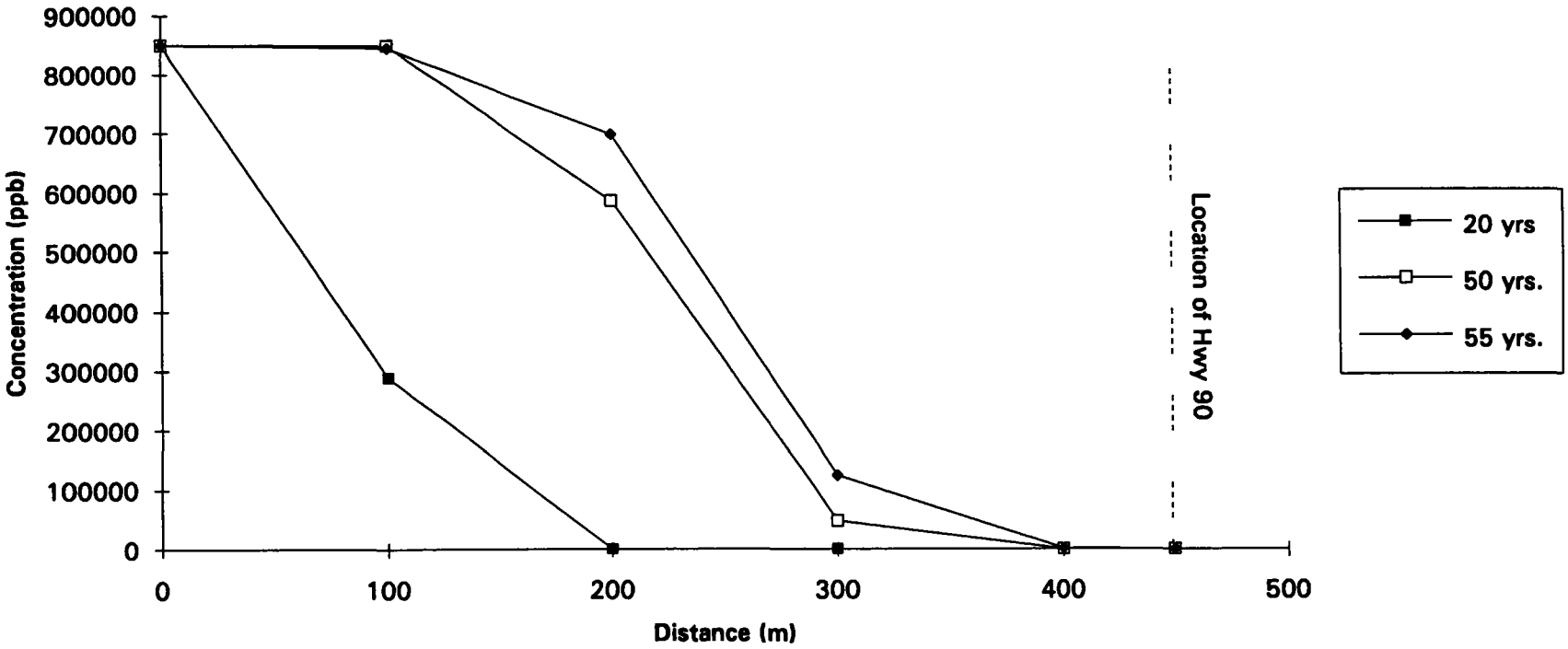

Table A-4: Transport in the INT Unit From INT West Area to Riverdale Subdivision

Distance to Riverdale = 122 m

Concentrations in ppb

Acetone (criteria = 3,500 ppb) Time to Riverdale = 7-8 yrs

Time	Distance						
	m	0	25	50	75	100	122
	ft.	0	82	164	246	328	400
2 yrs.		110000	5430	11.8	0	0	0
4 yrs.		110000	35800	2200	15	0 01	0
8 yrs.		110000	83200	36600	6190	332	9.2

Benzene (criteria = 5 ppb) Time to Riverdale = 23-24 yrs

Time	Distance						
	m	0	25	50	75	100	122
	ft	0	82	164	246	328	400
8 yrs.		3600	793	19.4	0 02	0	0
12 yrs		3600	1640	212	4 35	0 01	0
24 yrs.		3600	3060	1830	558	70 9	5 13

Vinyl Chloride (criteria = 2 ppb) Time to Riverdale = 15-16 yrs

Time	Distance						
	m	0	25	50	75	100	122
	ft.	0	82	164	246	328	400
8 yrs		16000	6490	628	7.89	0 01	0
10 yrs.		16000	8820	1740	72.7	0.5	0
16 yrs.		16000	13200	7000	1700	155	7 6

1,2 DCA (criteria = 5 ppb) Time to Riverdale = 9-10 yrs

Time	Distance						
	m	0	25	50	75	100	122
	ft.	0	82	164	246	328	400
5 yrs.		8700	4160	564	12.9	0 05	0
8 yrs.		8700	6570	2890	489	26 2	0 73
10 yrs.		8700	7470	4610	1470	200	15 7

Chloroform (criteria = 100 ppb) Time to Riverdale = 15-16 yrs

Time	Distance						
	m	0	25	50	75	100	122
	ft.	0	82	164	246	328	400
4 yrs.		250	51	1 2	0	0	0
8 yrs		250	151	42 9	3 4	0 06	0
16 yrs		250	222	177	96 5	29 9	6 09

Figure A-6
Acetone Transport in the INT
From West End of French Lagoon to Riverdale

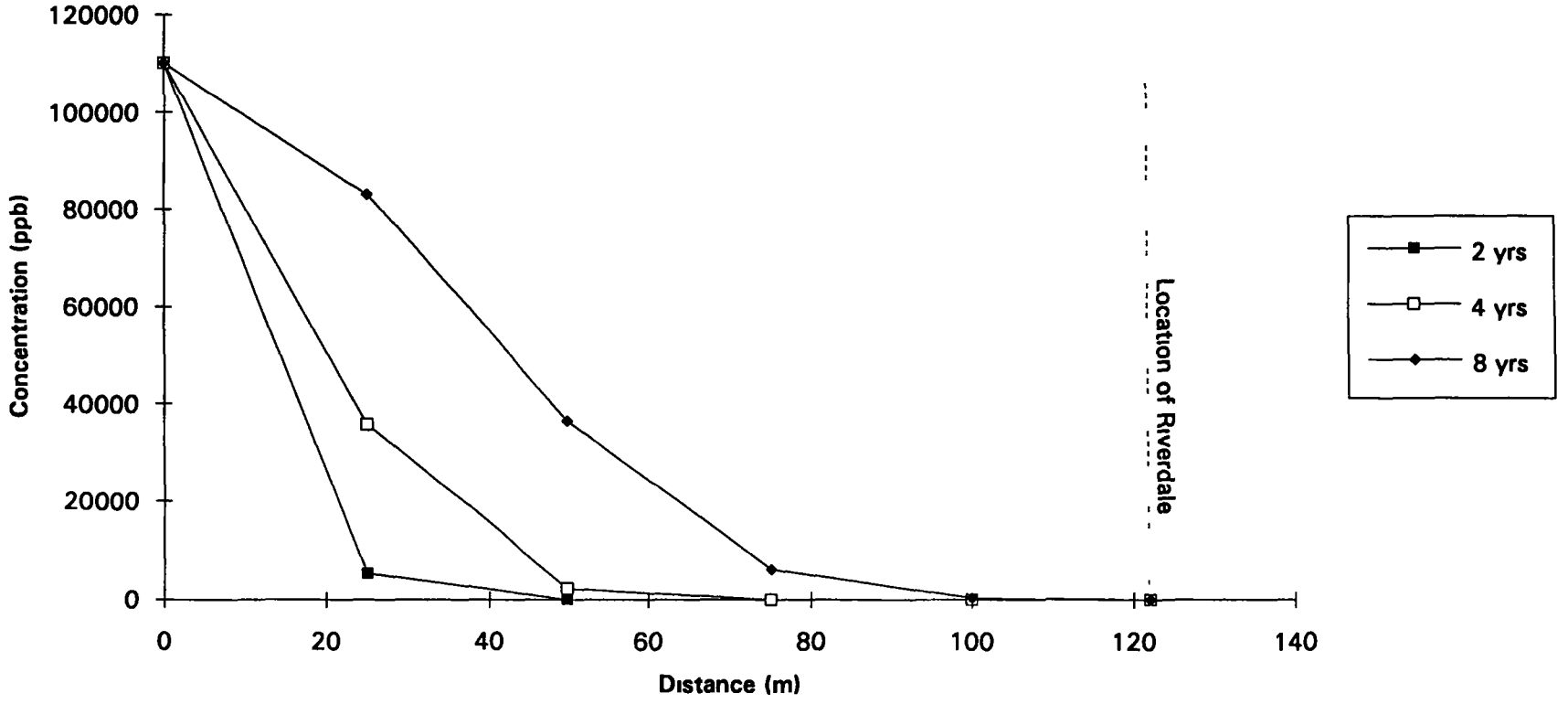

Figure A-7
Benzene Transport in the INT
From West End of French Lagoon to Riverdale

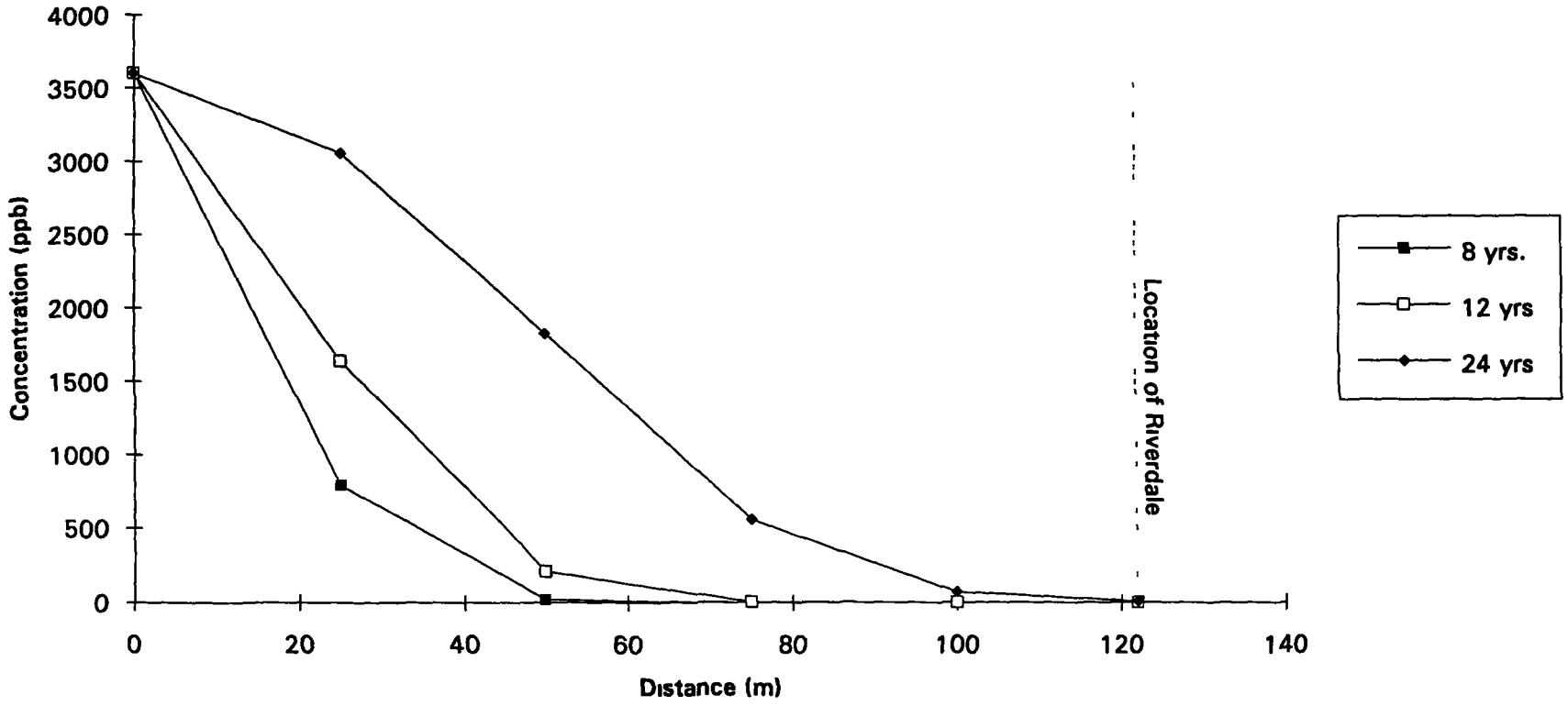

Figure A-8
Vinyl Chloride Transport in the INT
From West End of French Lagoon to Riverdale

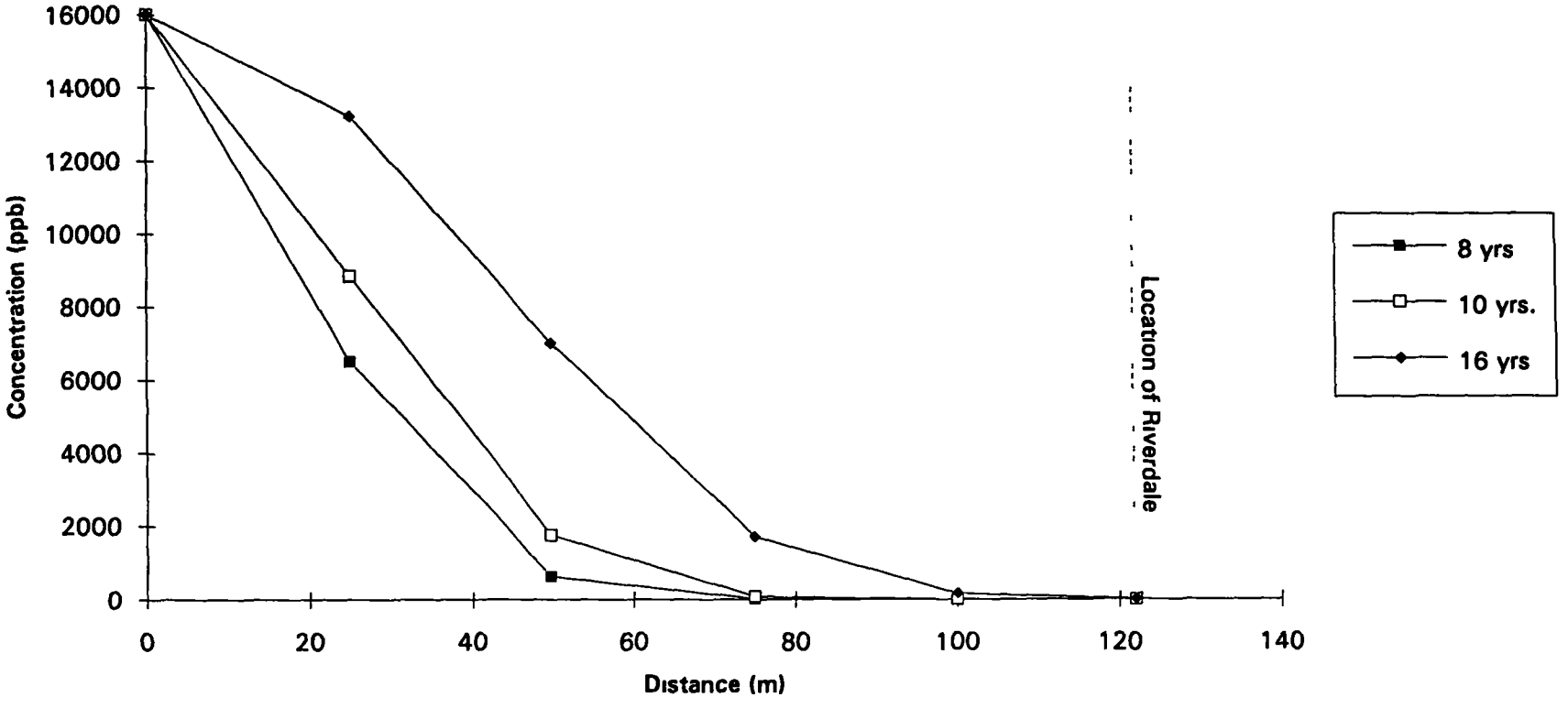

Figure A-9
1,2 DCA Transport in the INT
From West End of French Lagoon to Riverdale

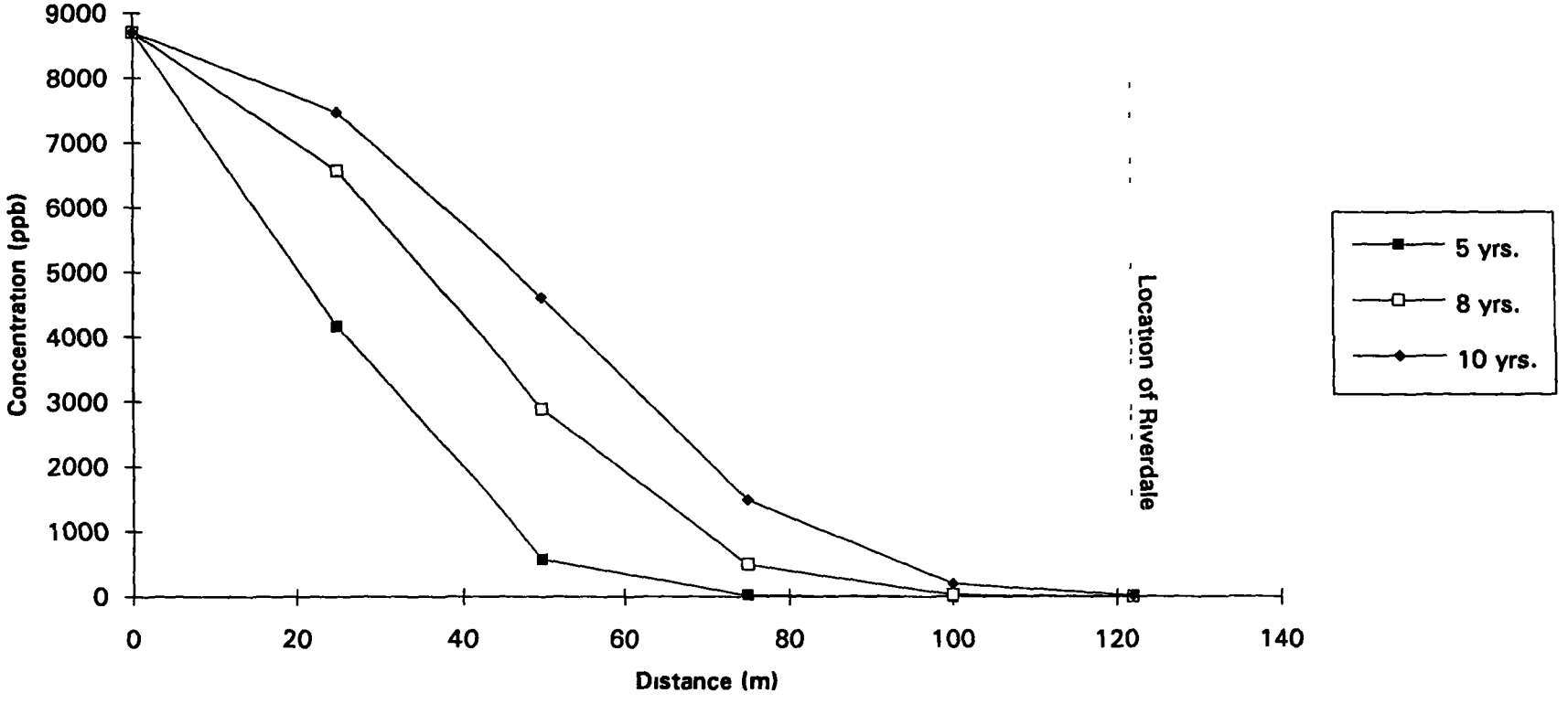

Figure A-10
Chloroform Transport in the INT
From West End of French Lagoon to Riverdale

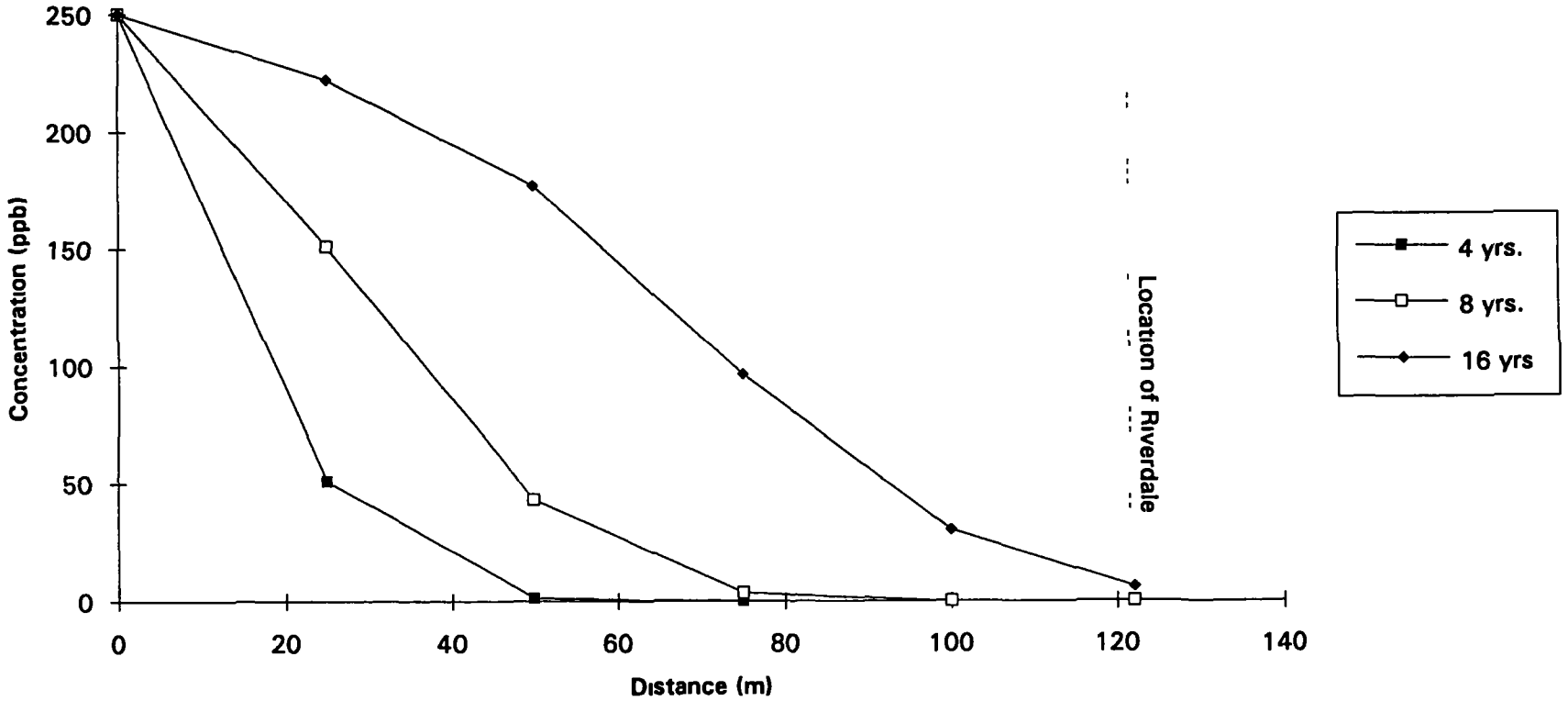

Table A-5: Transport in the S1-Unit From S1-16 Area to East Slough

Distance to East Slough = 24 m

Concentrations in ppb

Acetone (criteria = 3,500 ppb) Time to East Slough = 4-5 days

Time	Distance						
	m	0	5	10	15	20	25
	ft.	0	16	33	49	66	82
2 days		33443	737	45.9	3 15	0	0
4 days		33443	2500	277	15 6	0 05	0
5 days		33443	6560	2610	723	142	19.2

Benzene (criteria = 5 ppb) Time to East Slough = 4-5 weeks

Time	Distance						
	m	0	5	10	15	20	25
	ft.	0	16	33	49	66	82
2 weeks		3800	338	49.6	3 7	0 2	0
4 weeks		3800	711	251	64 4	11 1	1.3
5 weeks		3800	841	379	123	29 9	5 26

Vinyl Chloride (criteria = 2 ppb) Time to East Slough = 4-5 weeks

Time	Distance						
	m	0	5	10	15	20	25
	ft.	0	16	33	49	66	82
2 weeks		1400	174	43 6	5 4	0 5	0.03
4 weeks		1400	342	160	56.7	15 8	3.2
5 weeks		1400	393	224	97	34 1	9.65

1,2 DCA (criteria = 5 ppb) Time to East Slough = 13-14 days

Time	Distance						
	m	0	5	10	15	20	25
	ft.	0	16	33	49	66	82
3 days		6600	214	7.5	0 06	0	0
7 days		6600	702	142	15 3	0 83	0 02
14 days		6600	1420	595	186	41 9	6 7

Chloroform (criteria = 100 ppb) Time to East Slough =17-18 days

Time	Distance						
	m	0	5	10	15	20	25
	ft.	0	16	33	49	66	82
5 days		3700	466	116	17	1 4	0 06
10 days		3700	661	234	57.5	9 43	1 01
18 days		3700	835	364	120	29 2	5 1

Figure A-11
Benzene Transport in the S1
From S1-16 Area to the East Slough

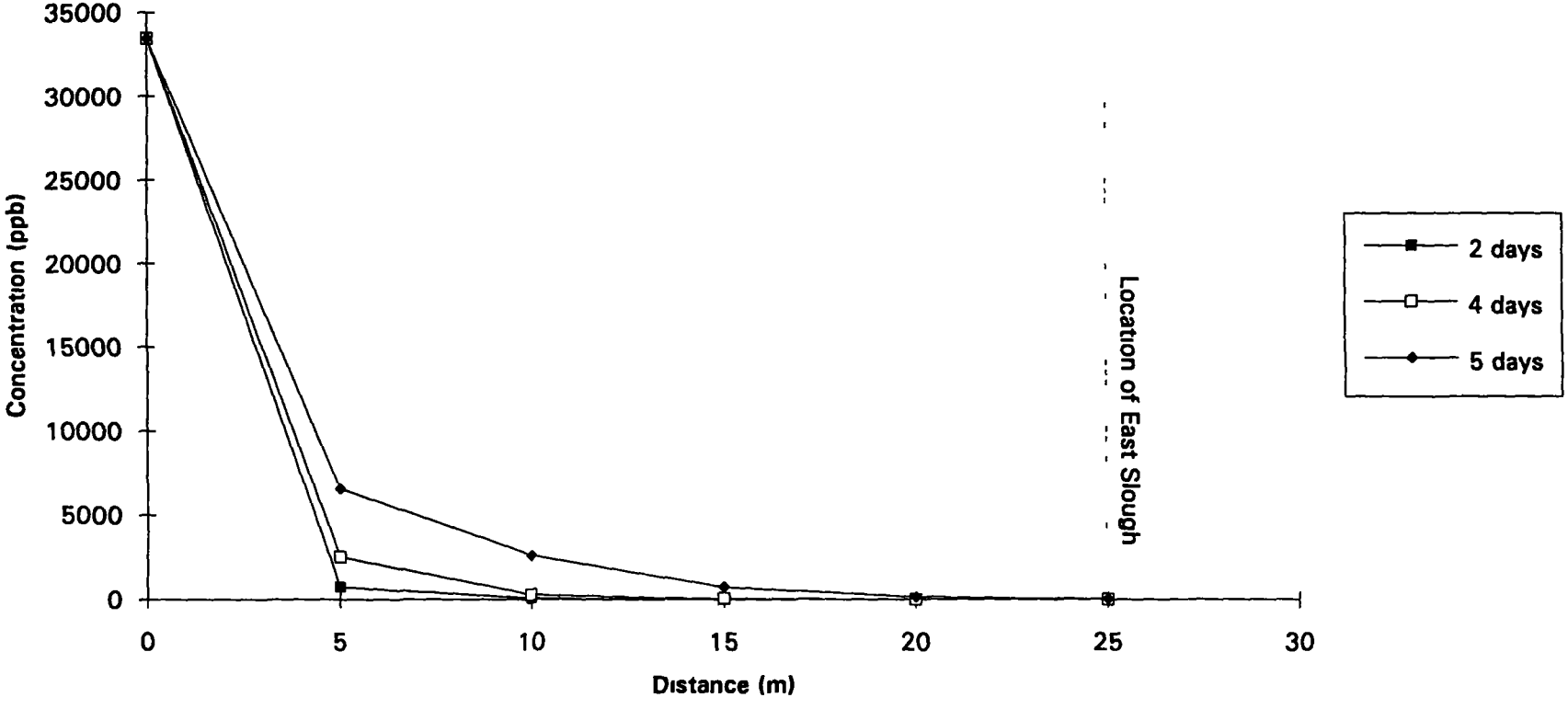

Figure A-12
Benzene Transport in the S1
From S1-16 Area to the East Slough

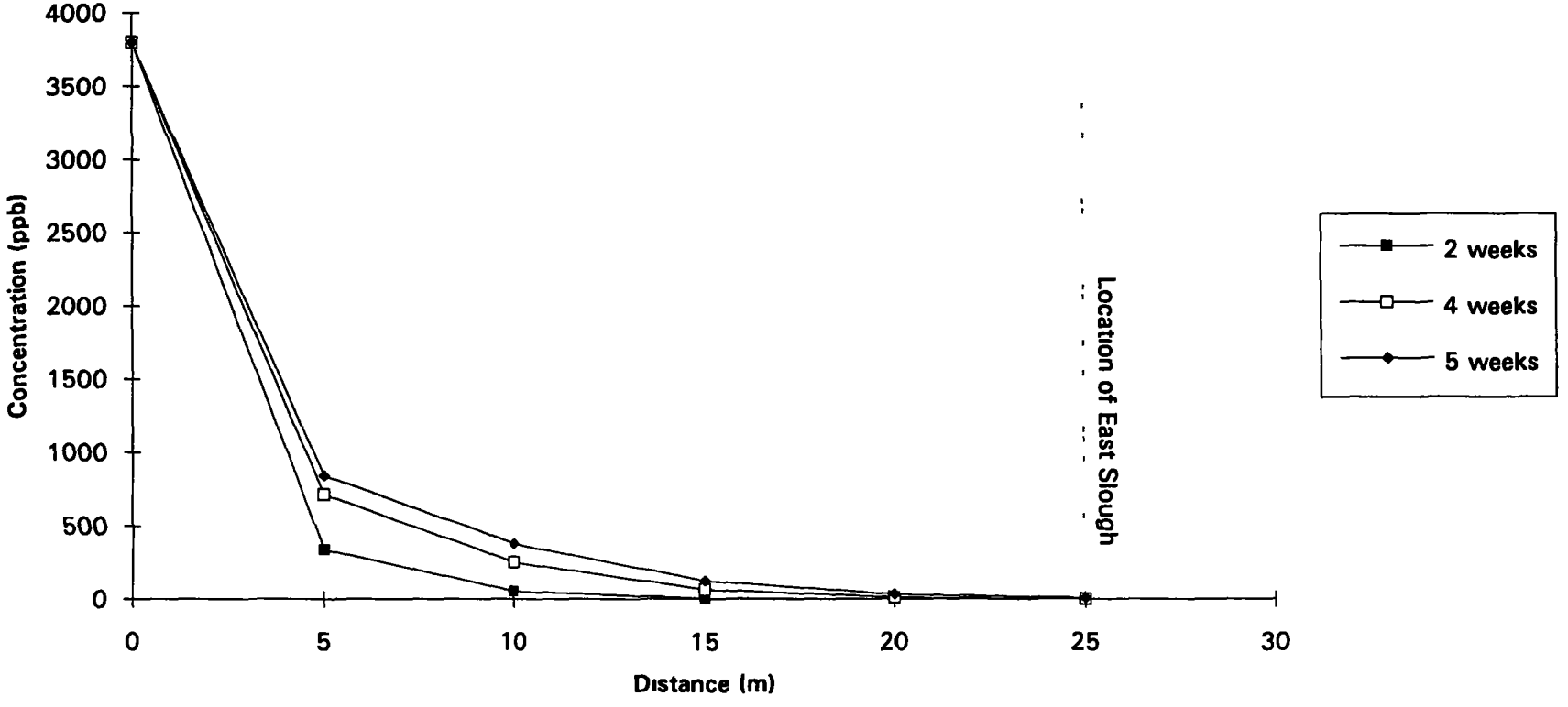

Figure A-13
Vinyl Chloride Transport in the S1
From S1-16 Area to the East Slough

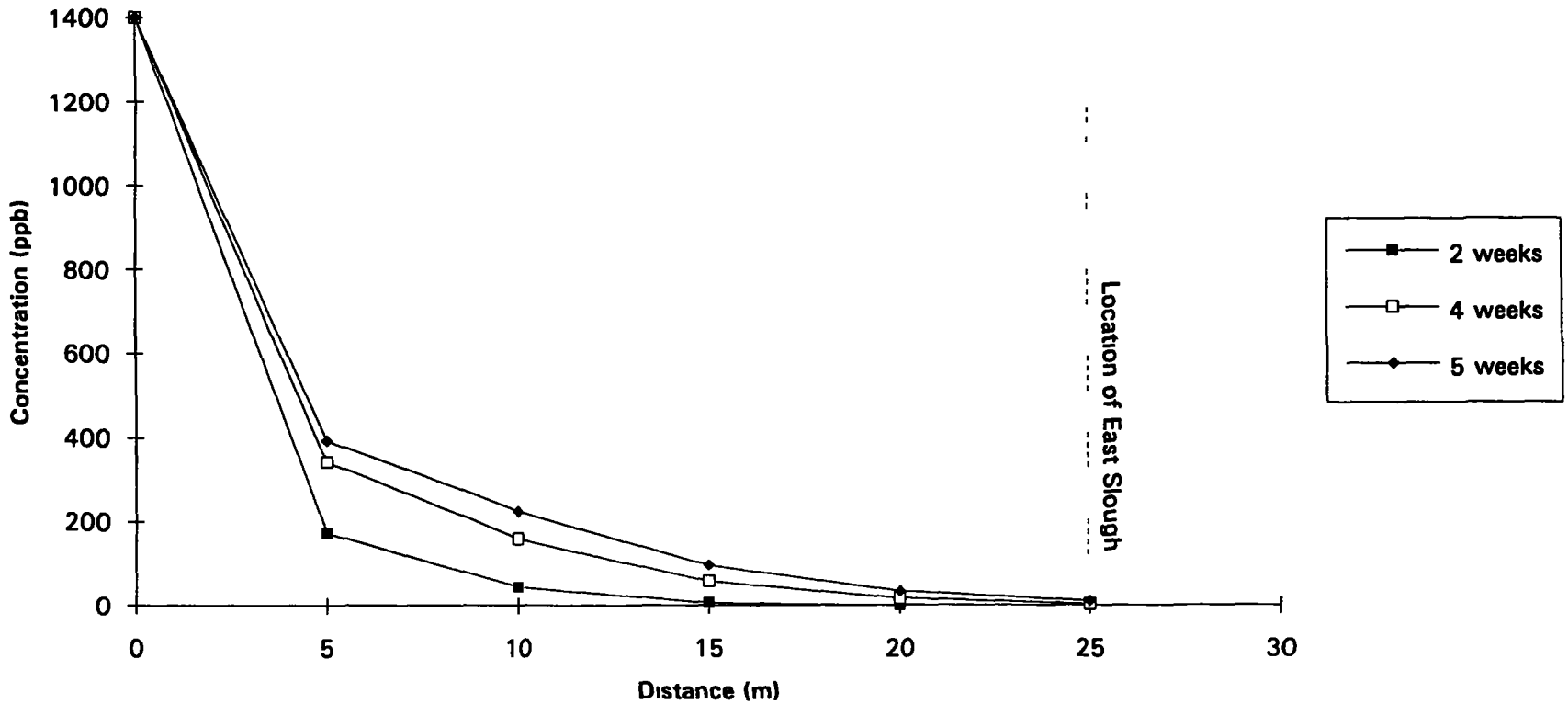

Figure A-14
1,2 DCA Transport in the S1
From S1-16 Area to the East Slough

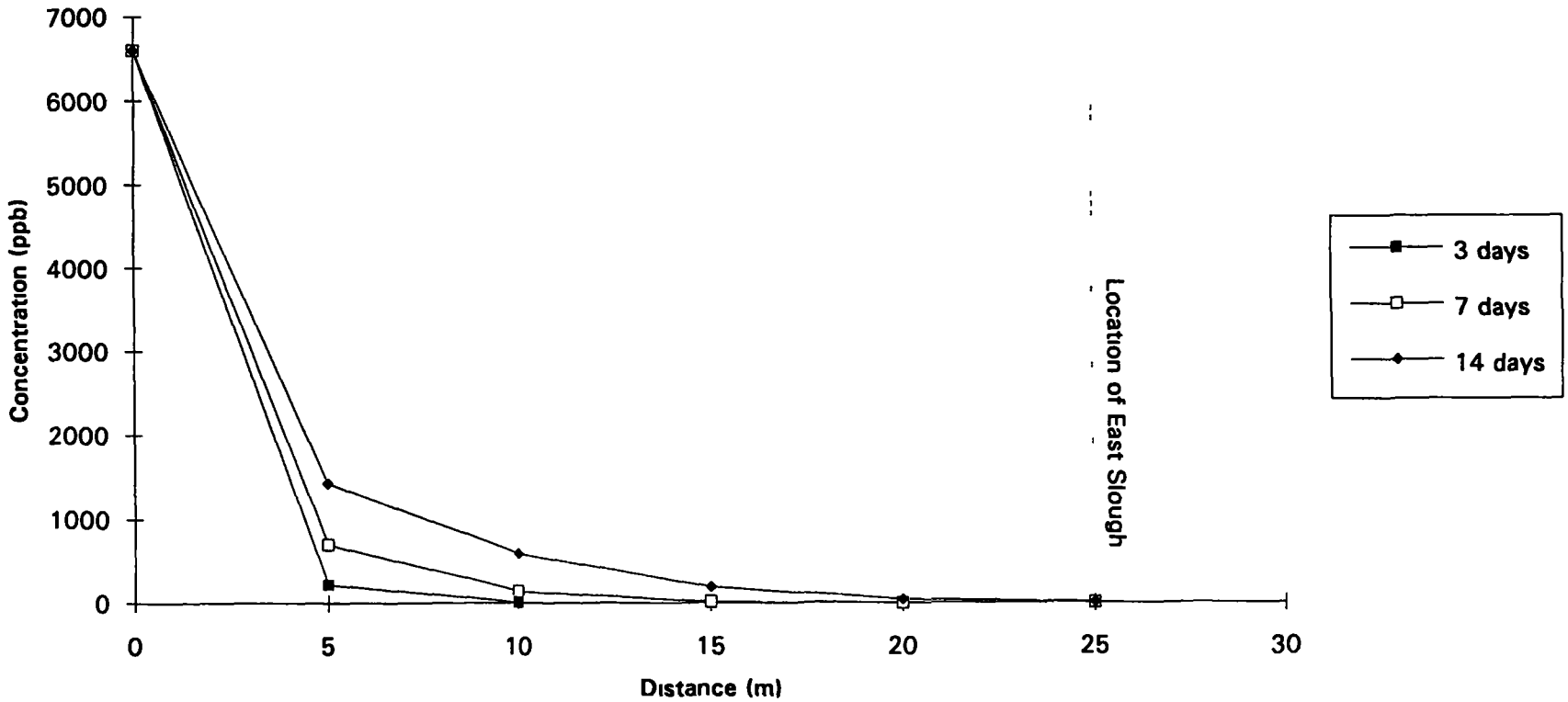

Figure A-15
Chloroform Transport in the S1
From S1-16 Area to the East Slough

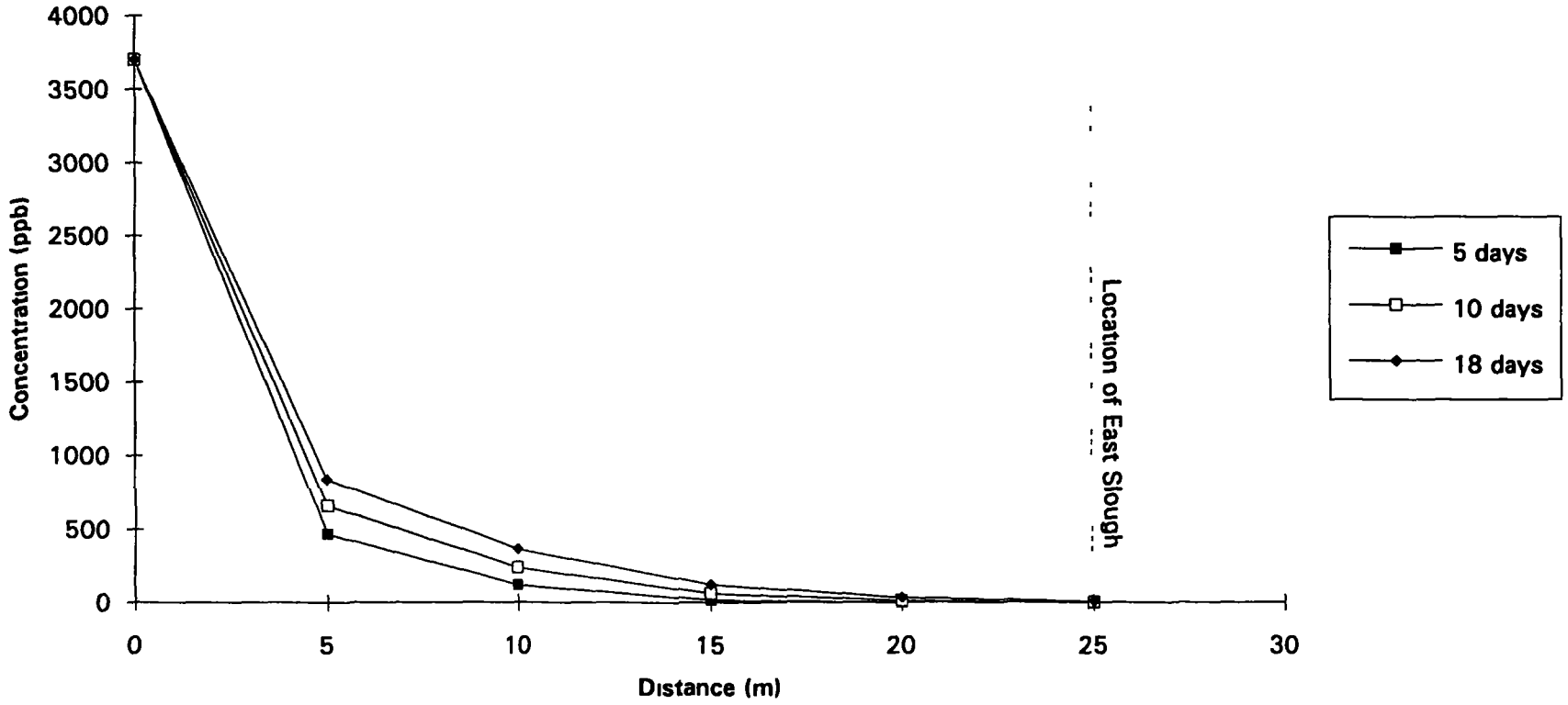

Table A-6: Transport in the S1-Unit From S1-16 Area to East Pond

Distance to East Pond = 75 m

Concentrations in ppb

Acetone (criteria = 3,500 ppb)

Time to East Pond = 2-3 months

Time	Distance							
	m	0	5	10	20	40	60	75
	ft.	0	16	33	66	131	197	246
1 month		33443	4320	3450	2280	45 2	0	0
2 months		33443	13200	10500	8050	640	23 8	0.07
3 months		33443	15200	13400	11800	3220	300	30 8

Benzene (criteria = 5 ppb)

Time to East Pond = 19-20 months

Time	Distance							
	m	0	5	10	20	40	60	75
	ft.	0	16	33	66	131	197	246
2 months		3800	500	137	2	0	0	0
10 months		3800	1880	1400	596	32 5	2 9	0
20 months		3800	2690	2370	1640	472	60 3	7 1

Vinyl Chloride (criteria = 2 ppb)

Time to East Pond = 15-16 months

Time	Distance							
	m	0	5	10	20	40	60	75
	ft.	0	16	33	66	131	197	246
4 months		1400	448	274	53 4	0	0	0
8 months		1400	718	564	257	18 7	2 6	0
16 months		1400	1010	921	662	220	35 4	5 3

1,2 DCA (criteria = 5 ppb)

Time to East Pond = 7-8 months

Time	Distance							
	m	0	5	10	20	40	60	75
	ft.	0	16	33	66	131	197	246
2 months		6600	1670	1510	152	0 4	0	0
4 months		6600	2890	2480	923	42 8	3 1	0
8 months		6600	4290	3540	2660	706	78.3	8

Chloroform (criteria = 100 ppb)

Time to East Pond = 9-10 months

Time	Distance							
	m	0	5	10	20	40	60	75
	ft.	0	16	33	66	131	197	246
2 months		3700	1470	1100	342	7 3	0	0
5 months		3700	1590	1340	554	27 4	2 1	0
10 months		3700	2490	2290	1540	424	50 2	5 5

Figure A-16
Acetone Transport in the S1
From S1-16 Area to the East Pond

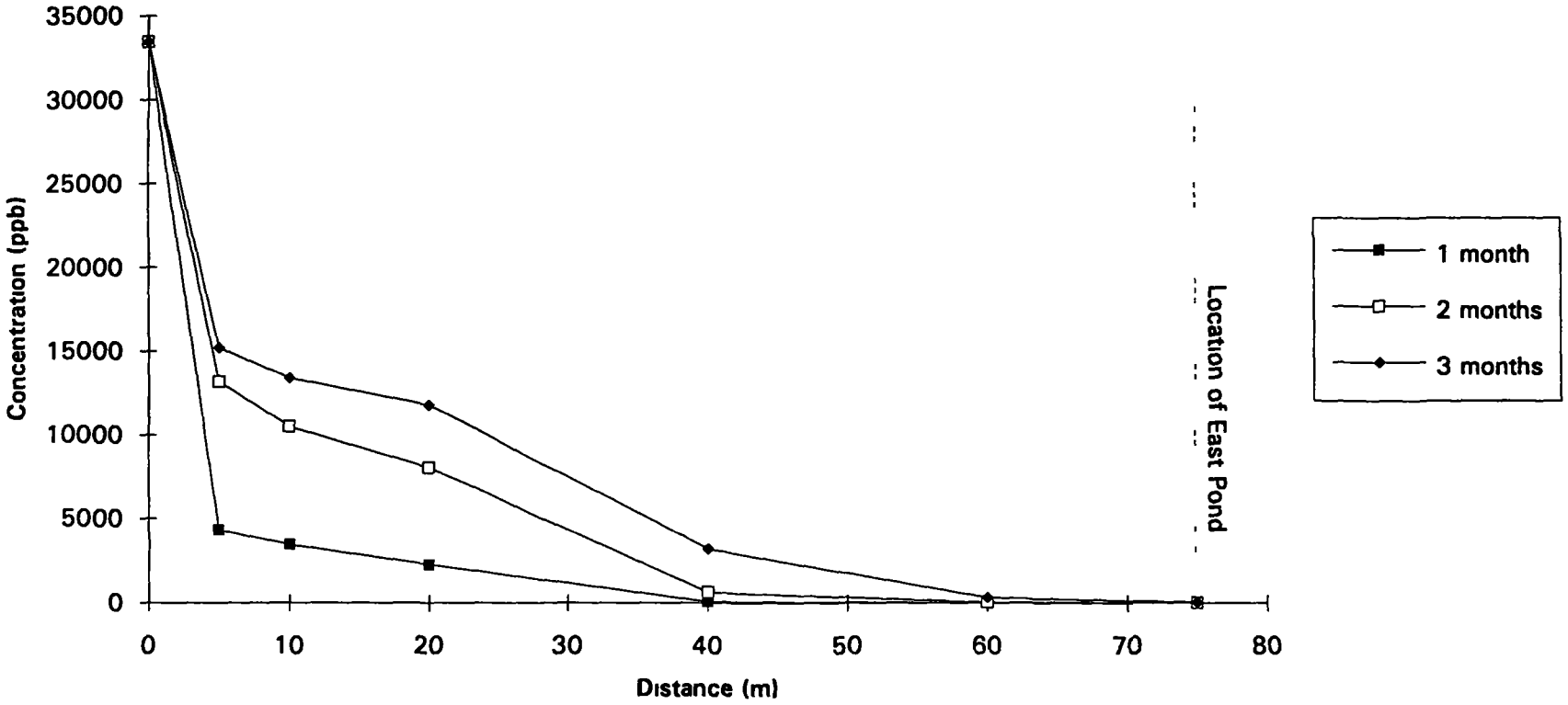

Figure A-17
Benzene Transport in the S1
From S1-16 Area to the East Pond

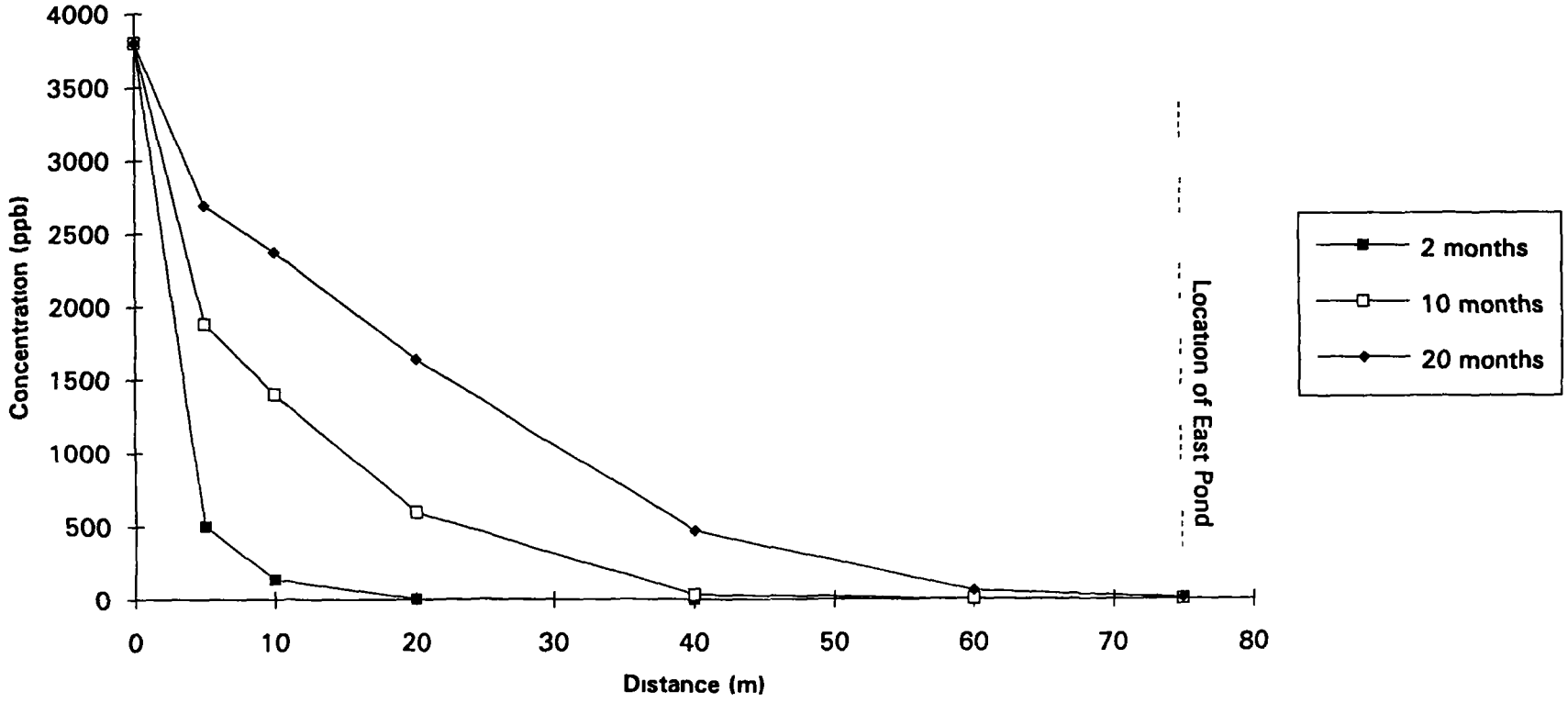

Figure A-18
Vinyl Chloride Transport in the S1
From S1-16 Area to the East Pond

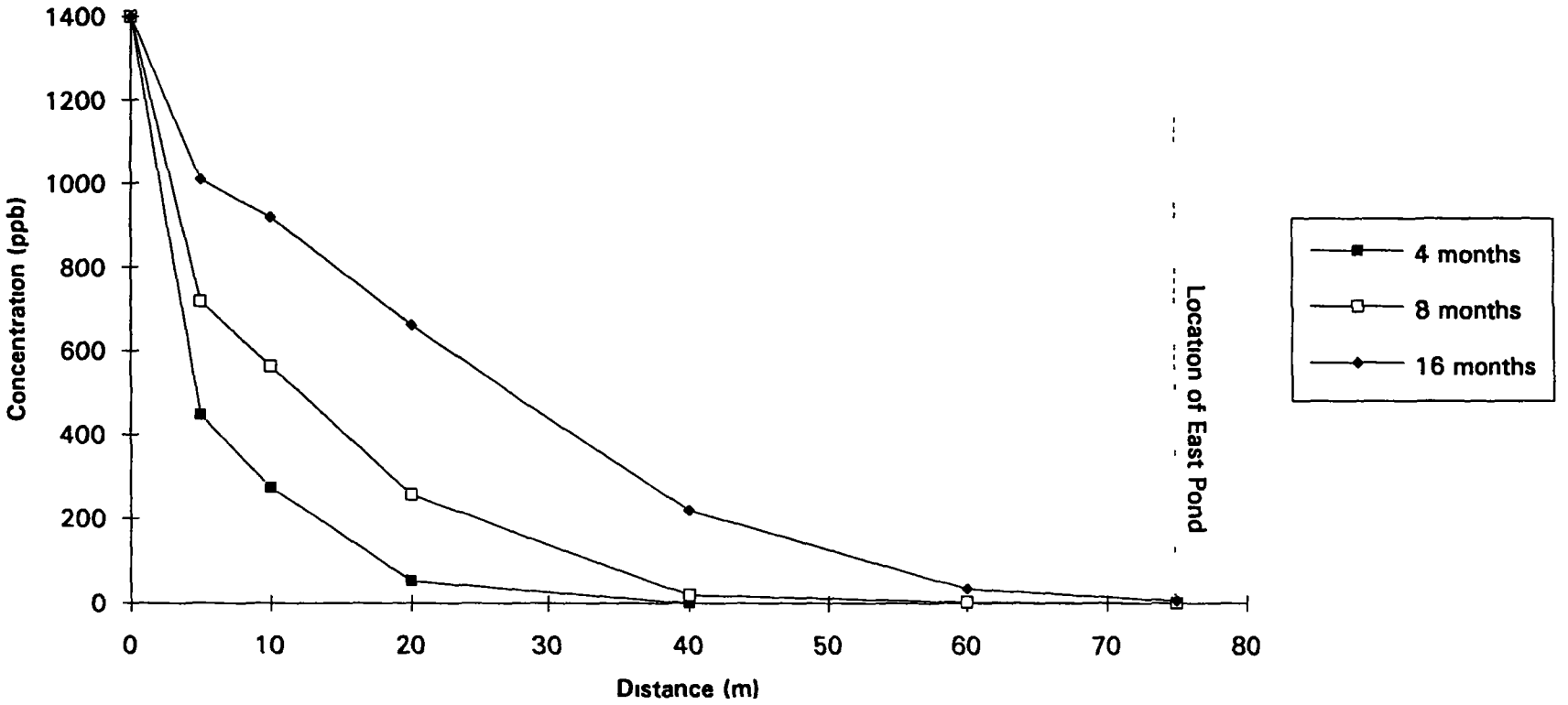

Figure A-19
1,2 DCA Transport in the S1
From S1-16 Area to the East Pond

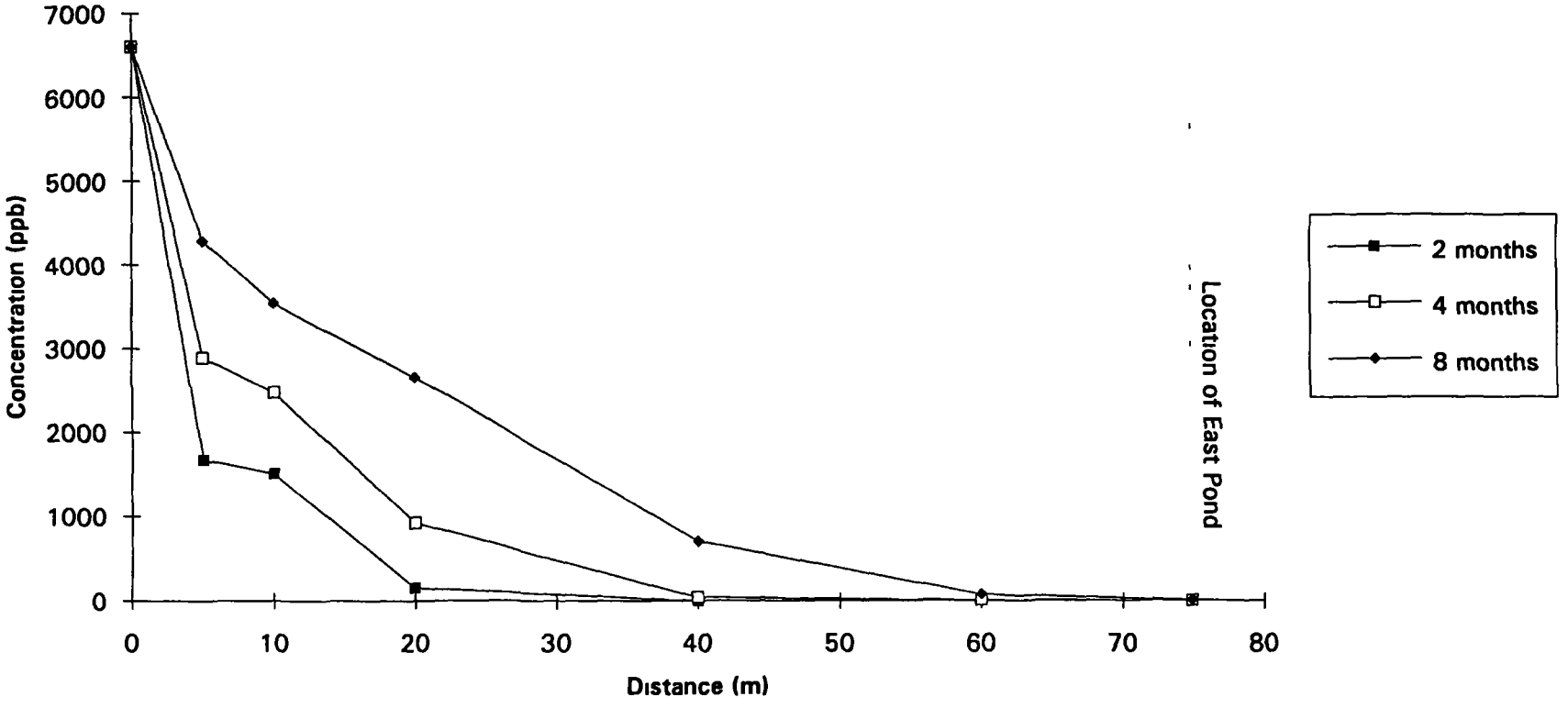

Figure A-20
Chloroform Transport in the S1
From S1-16 Area to the East Pond

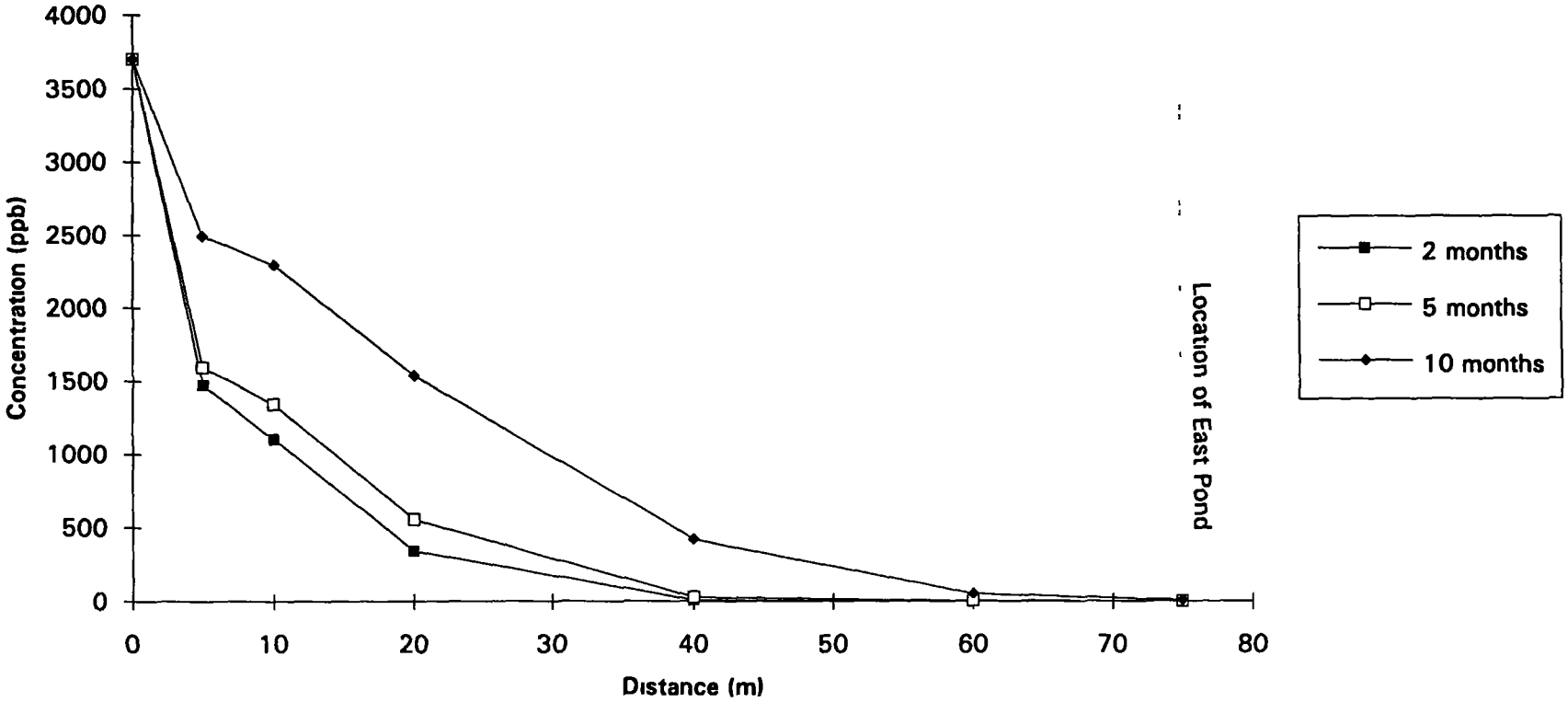

Table A-7: Transport in the S1-Unit From S1-13 Area to South Pond

Distance to South Pond = 150 m

Concentrations in ppb

Acetone (criteria = 3,500 ppb) Time to South Pond = 58-59 wks

Time	Distance							
	m	0	10	20	50	75	100	150
	ft.	0	33	66	164	246	328	492
10 wks.		76036	19600	5690	3.52	0	0	0
24 wks		76036	42400	26900	1840	32.9	0 09	0
59 wks		76036	65600	58700	29400	9400	1610	5 8

Benzene (criteria = 5 ppb) Time to South Pond = 9-9 5 yrs

Time	Distance							
	m	0	10	20	50	75	100	150
	ft.	0	33	66	164	246	328	492
2 yrs.		1300	559	273	4.8	0	0	0
4 yrs.		1300	881	655	125	9 8	0 2	0
9 5 yrs		1300	1160	1120	779	417	150	7 3

Vinyl Chloride (criteria = 2 ppb) Time to South Pond = 5.5-6 yrs

Time	Distance							
	m	0	10	20	50	75	100	150
	ft	0	33	66	164	246	328	492
1 yr		7278	2230	818	2 4	0	0	0
3 yrs		7278	5090	3920	785	66.8	1 8	0
6 yrs		7278	6570	6110	3730	1620	431	5 6

1,2 DCA (criteria = 5 ppb) Time to South Pond = 37-38 months

Time	Distance							
	m	0	10	20	50	75	100	150
	ft	0	33	66	164	246	328	492
6 months		20000	5320	1570	1 1	0	0	0
18 months		20000	13000	9310	1320	68 1	0 9	0
38 months		20000	17700	16100	9000	3390	734	5 2

Chloroform (criteria = 100 ppb) Time to South Pond = 40-41 months

Time	Distance							
	m	0	10	20	50	75	100	150
	ft	0	33	66	164	246	328	492
10 months		131131	47500	19900	118	0	0	0
20 months		131131	80600	55300	6050	213	1 6	0
41 months		131131	112000	99500	47700	14300	2230	6 2

Figure A-21
Acetone Transport in the S1
From S1-13 Area to the South Pond

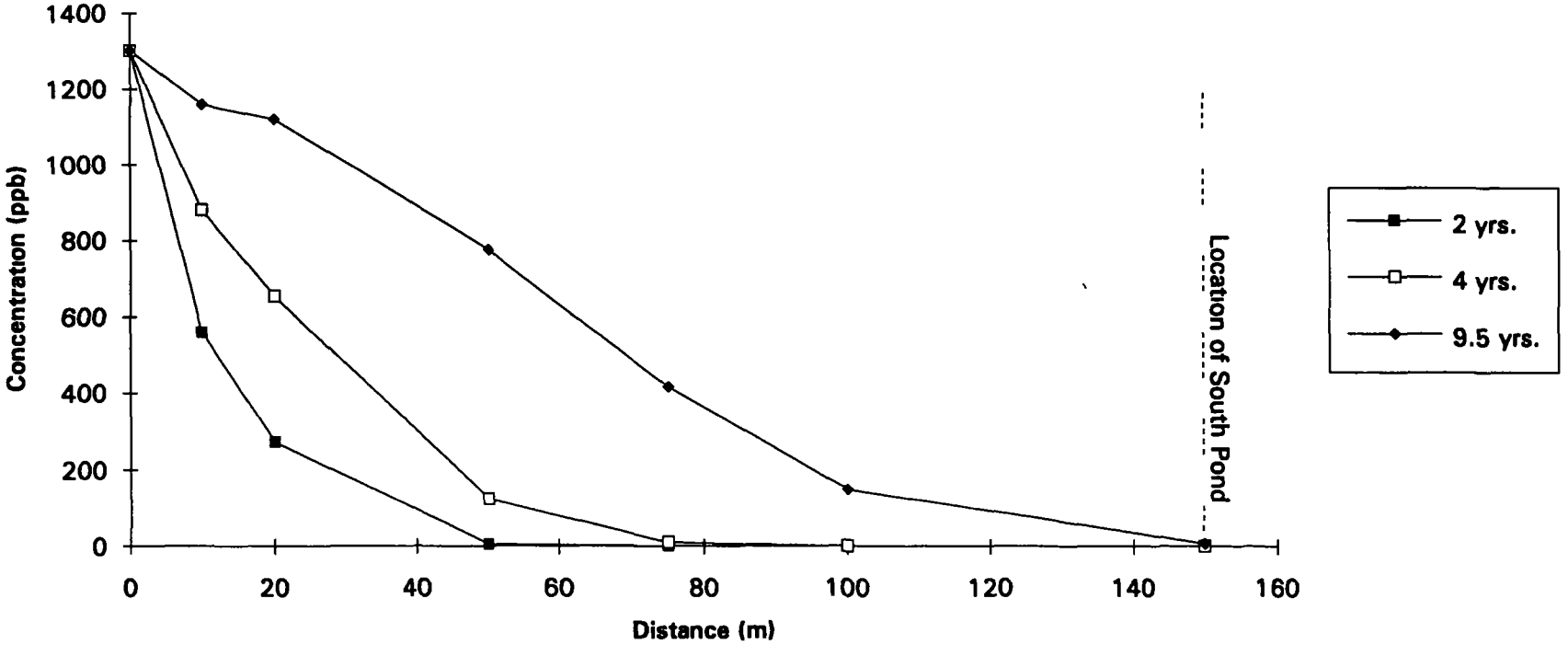

Figure A-22
Benzene Transport in the S1
From S1-13 Area to the South Pond

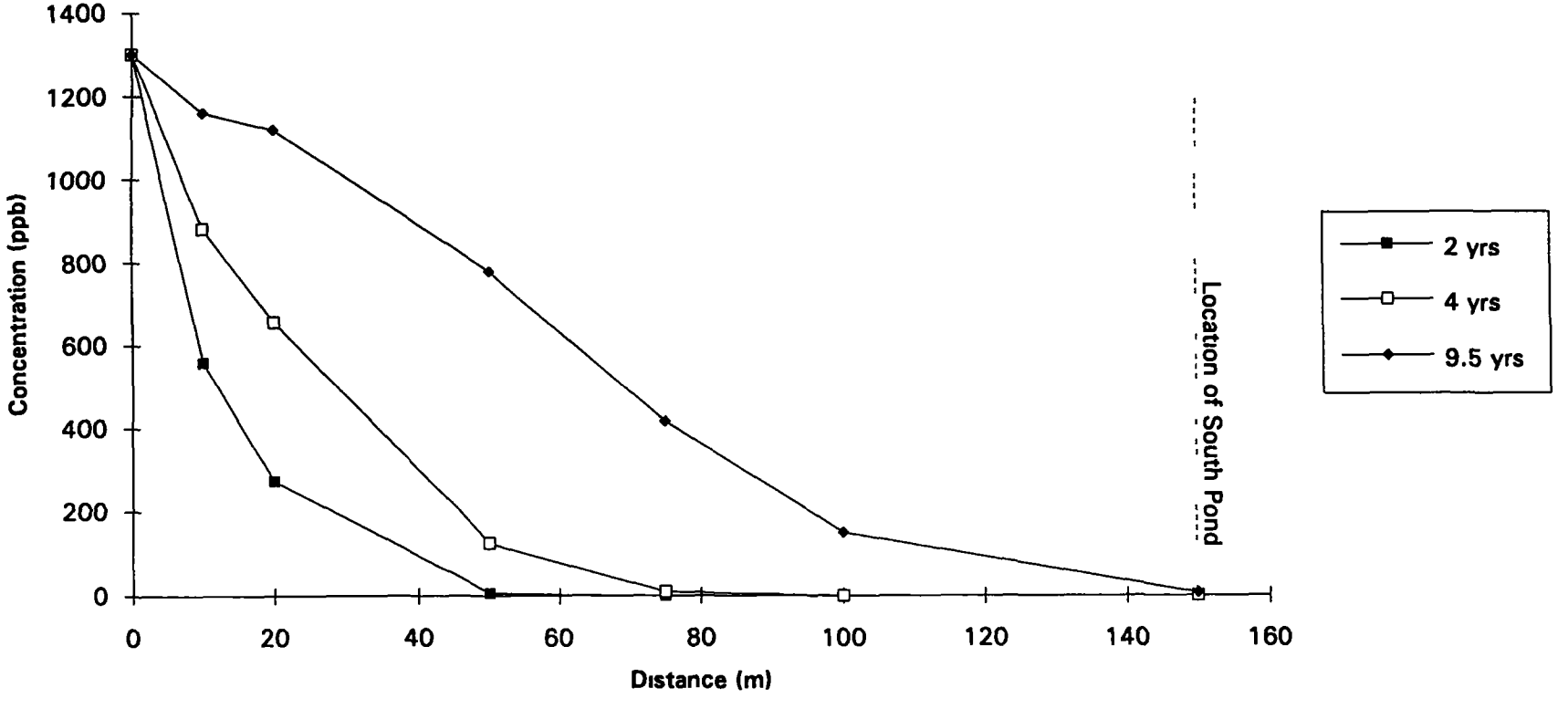

Figure A-23
Vinyl Chloride Transport in the S1
From S1-13 Area to the South Pond

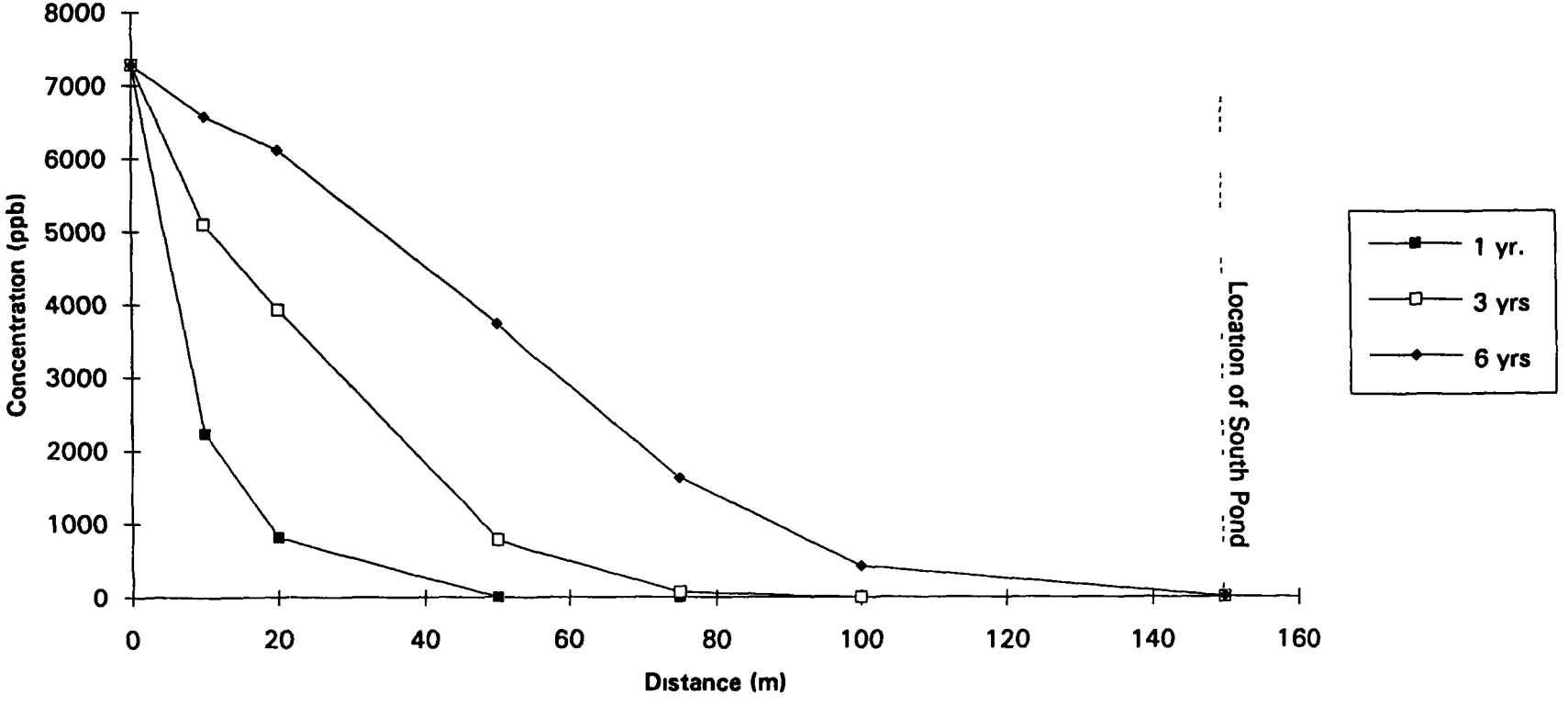

Figure A-24
1,2 DCA Transport in the S1
From S1-13 Area to the South Pond

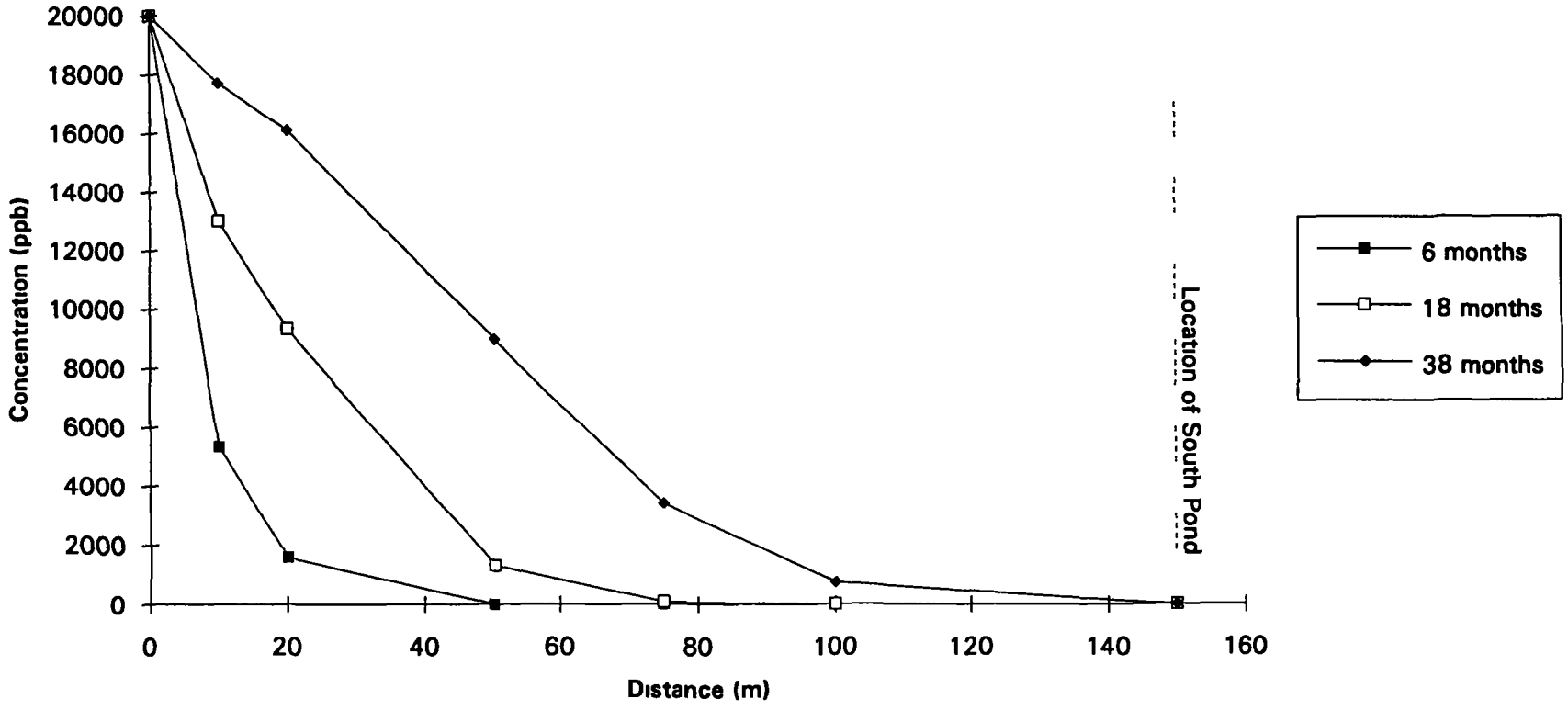

Figure A-25
Chloroform Transport in the S1
From S1-13 Area to the South Pond

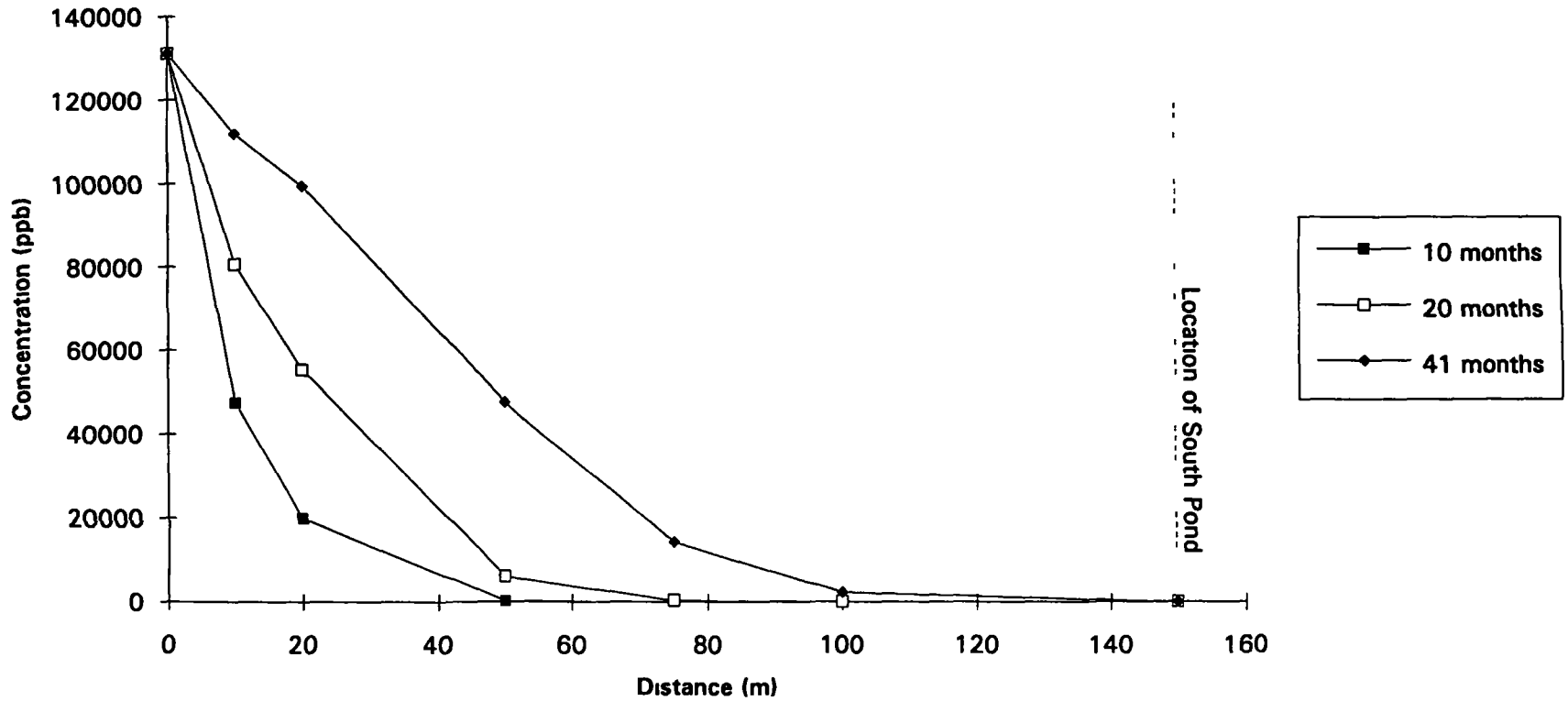

Table A-8: Transport in the S1-Unit From S1-13 Area to New Hwy 90

Distance to Highway 90 = 365 m

Concentrations in ppb

Acetone (criteria = 3,500 ppb) Time to highway = 11-12 months

Time	Distance						
	m	0	50	100	200	300	365
	ft.	0	164	328	656	984	1197
3 months		76036	26500	927	0	0	0
6 months		76036	60000	25200	9490	0	0
12 months		76036	74300	69400	23700	743	15 7

Benzene (criteria = 5 ppb) Time to highway = 7-7.5 years

Time	Distance						
	m	0	50	100	200	300	365
	ft	0	164	328	656	984	1197
2 years		1300	670	84.7	0	0	0
4 years		1300	1180	787	29 8	0.01	0
7.5 years		1300	1300	1270	787	160	8.63

Vinyl Chloride (criteria = 2 ppb) Time to highway = 40-41 months

Time	Distance						
	m	0	50	100	200	300	365
	ft	0	164	328	656	984	1197
2 years		7278	4670	2960	90 8	0 27	0
3 years		7278	5060	4590	1350	30 2	0 46
41 months		7278	5110	4850	2220	136	5 22

1,2 DCA (criteria = 5 ppb) Time to highway = 31-32 months

Time	Distance						
	m	0	50	100	200	300	365
	ft.	0	164	328	656	984	1197
1 year		20000	13000	2870	6.52	0	0
2 years		20000	19200	15200	1710	5 5	0 01
32 months		20000	19900	18600	7350	319	8 96

Chloroform (criteria = 100 ppb) Time to highway = 34-35 months

Time	Distance						
	m	0	50	100	200	300	365
	ft.	0	164	328	656	984	1197
1 year		131131	66700	7450	0.09	0	0
2 years		131131	119000	75800	2350	7 06	0
35 months		131131	129000	116000	30500	544	6 79

Figure A-26
Acetone Transport in the S1
From S1-13 Area to New Hwy 90

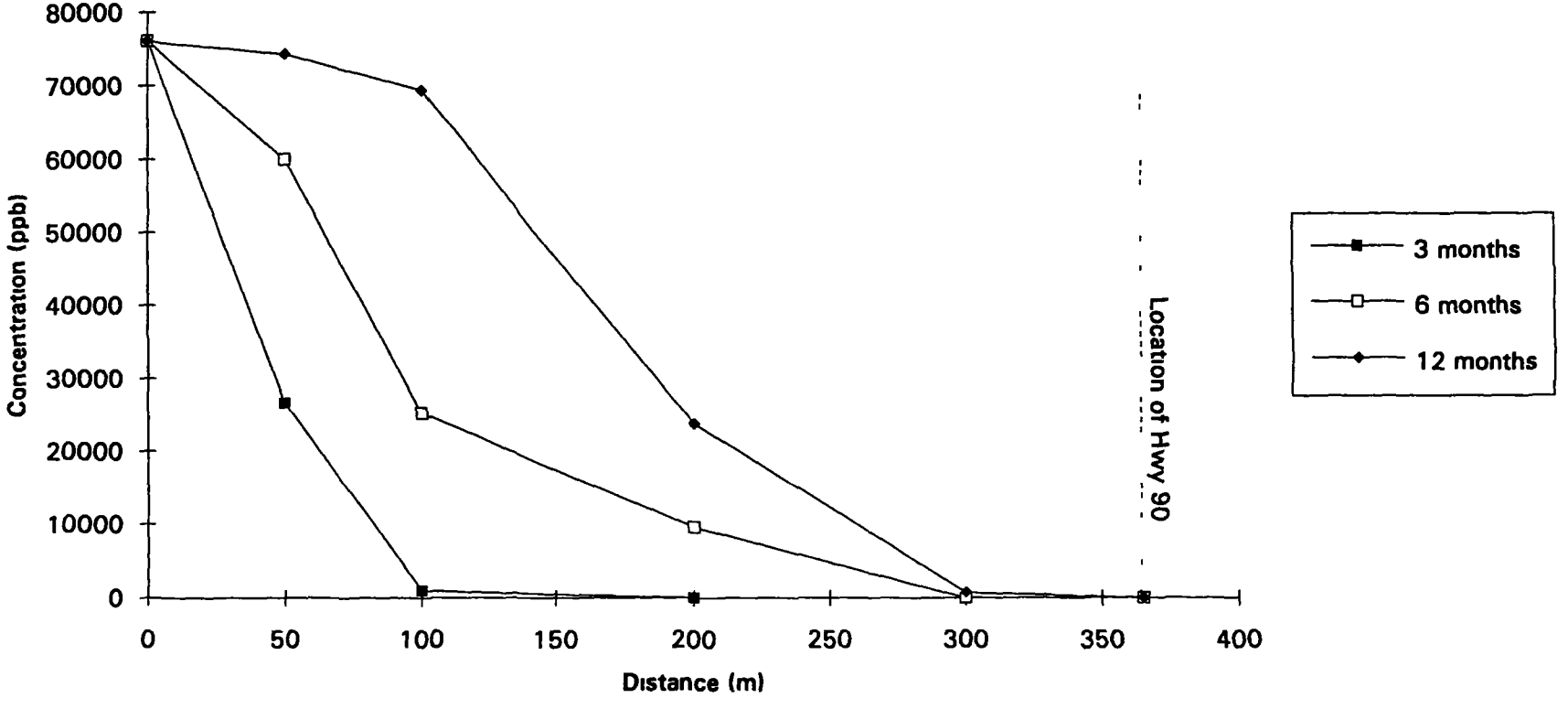

Figure A-27
Benzene Transport in the S1
From S1-13 Area to New Hwy 90

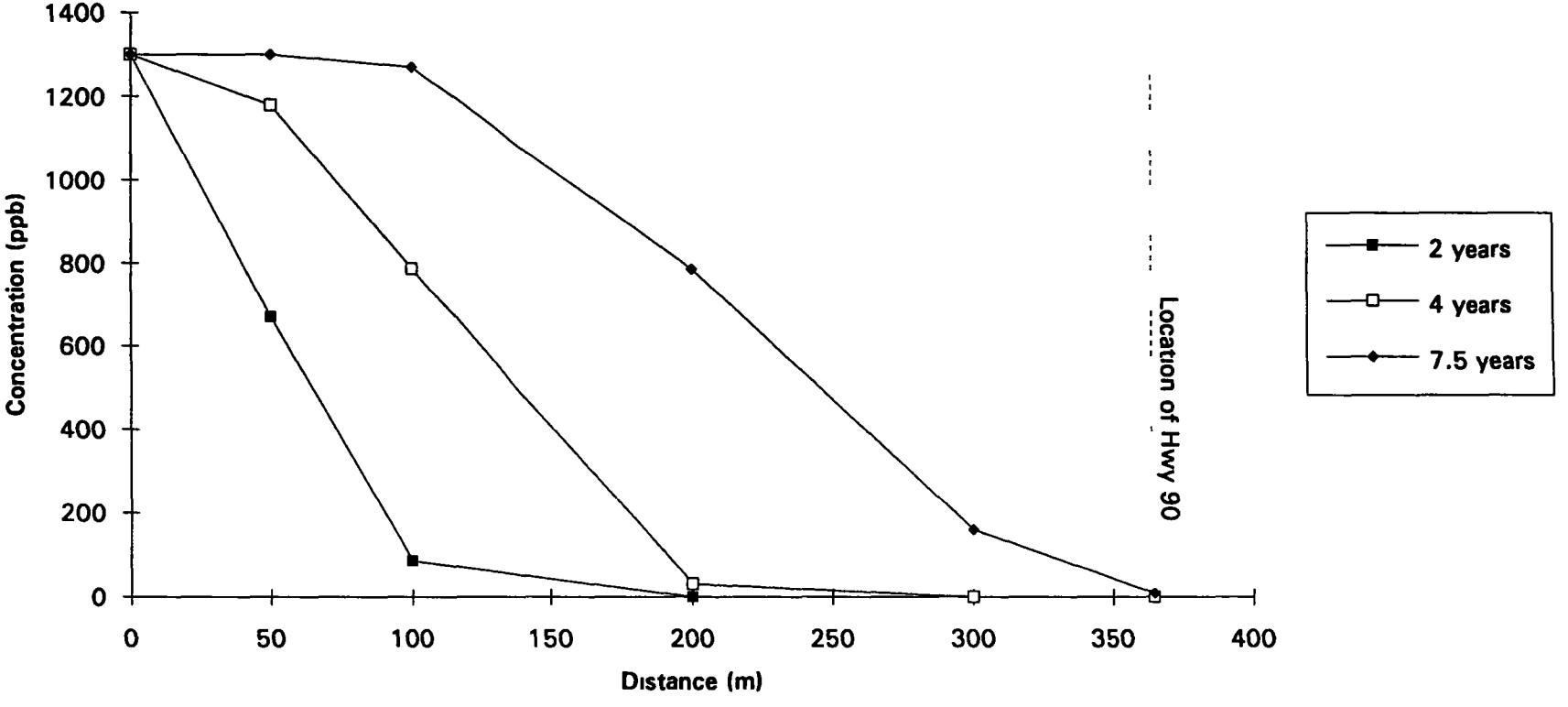

Figure A-28
Vinyl Chloride Transport in the S1
From S1-13 Area to New Hwy 90

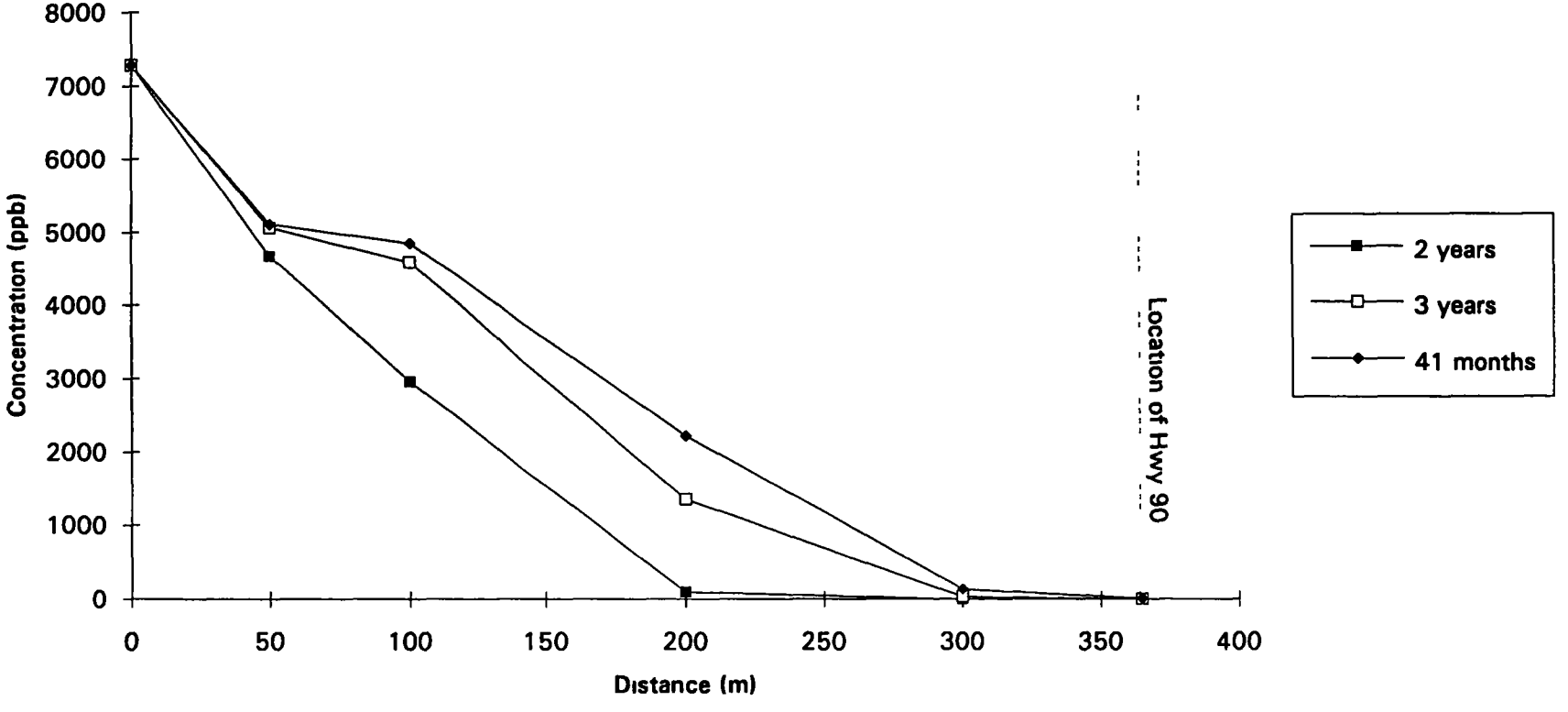

Figure A-29
1,2 DCA Transport in the S1
From S1-13 Area to New Hwy 90

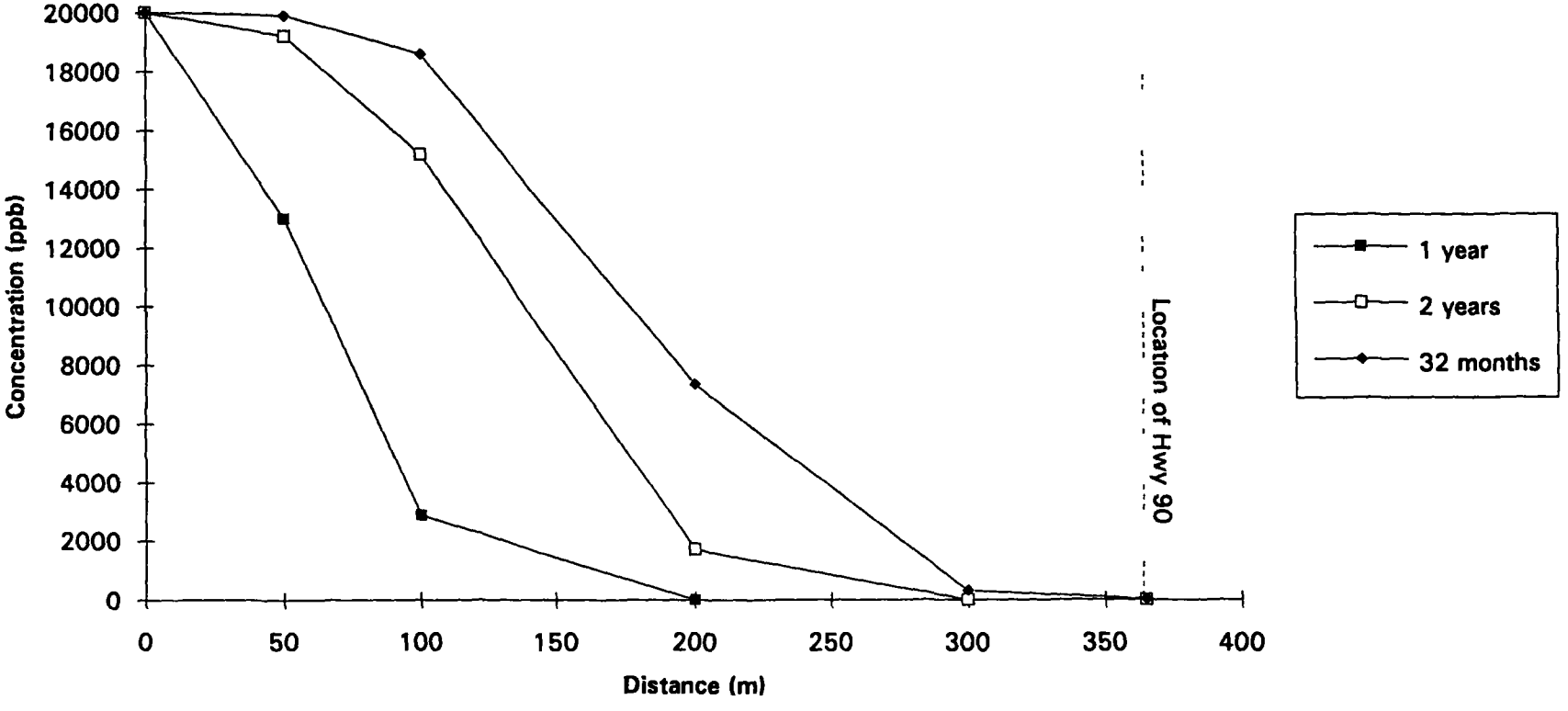

Figure A-30
Chloroform Transport in the S1
From S1-13 Area to New Hwy 90

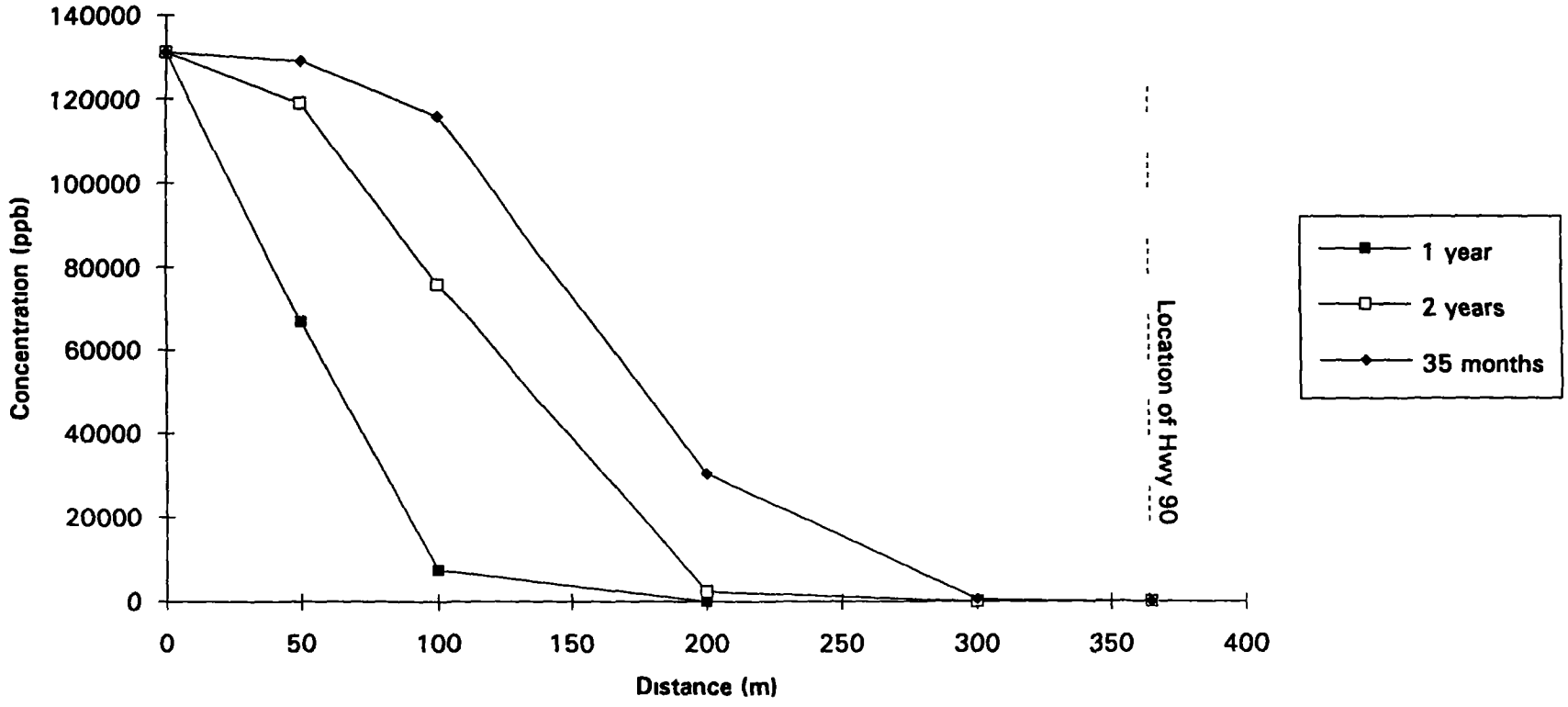

Table A-9: Transport in the INT-Unit From INT-11 Area to a Well North of Gulf Pump Road

Distance to well north of Gulf Pump Road = 3 m — Concentrations in ppb

Acetone (criteria = 3,500 ppb) — Time to hypothetical domestic well = < 1 day

Time	Distance						
	m	0	1	3	6	9	12
	ft.	0	3	10	20	30	39
1 day		81000	1420	98.9	0	0	0
5 days		81000	3010	2500	131	1 24	0
11days		81000	8500	6560	1710	178	9.08

Benzene (criteria = 5 ppb) — Time to hypothetical domestic well = 10-12 days

Time	Distance						
	m	0	1	3	6	9	12
	ft.	0	3	10	20	30	39
2 weeks		1200	67 1	7.4	0 01	0	0
10 weeks		1200	232	116	21.4	1 95	0 08
20 weeks		1200	353	236	92.1	25 9	5 08

Vinyl Chloride (criteria = 2 ppb) — Time to hypothetical domestic well = 4-5 days

Time	Distance						
	m	0	1	3	6	9	12
	ft.	0	3	10	20	30	39
6 days		6000	282	7.72	0	0	0
36 days		6000	1020	380	39.6	1 48	0.02
74 days		6000	1560	874	255	46 6	5 12

1,2 DCA (criteria = 5 ppb) — Time to hypothetical domestic well < 1 day

Time	Distance						
	m	0	1	3	6	9	12
	ft.	0	3	10	20	30	39
1 day		860000	7100	6.7	0	0	0
14 days		860000	113000	31700	1440	14 1	0.03
22 days		860000	151000	60500	7320	346	5 9

Chloroform (criteria = 10 ppb) — Time to hypothetical domestic well < 1 day

Time	Distance						
	m	0	1	3	6	9	12
	ft.	0	3	10	20	30	39
2 days		850000	19100	42 8	0	0	0
14 days		850000	97800	22200	551	2 02	0
27 days		850000	148000	59500	7140	334	5 12

Figure A-31
Acetone Transport in the INT
From INT-11 Area to a Well North of Gulf Pump Road

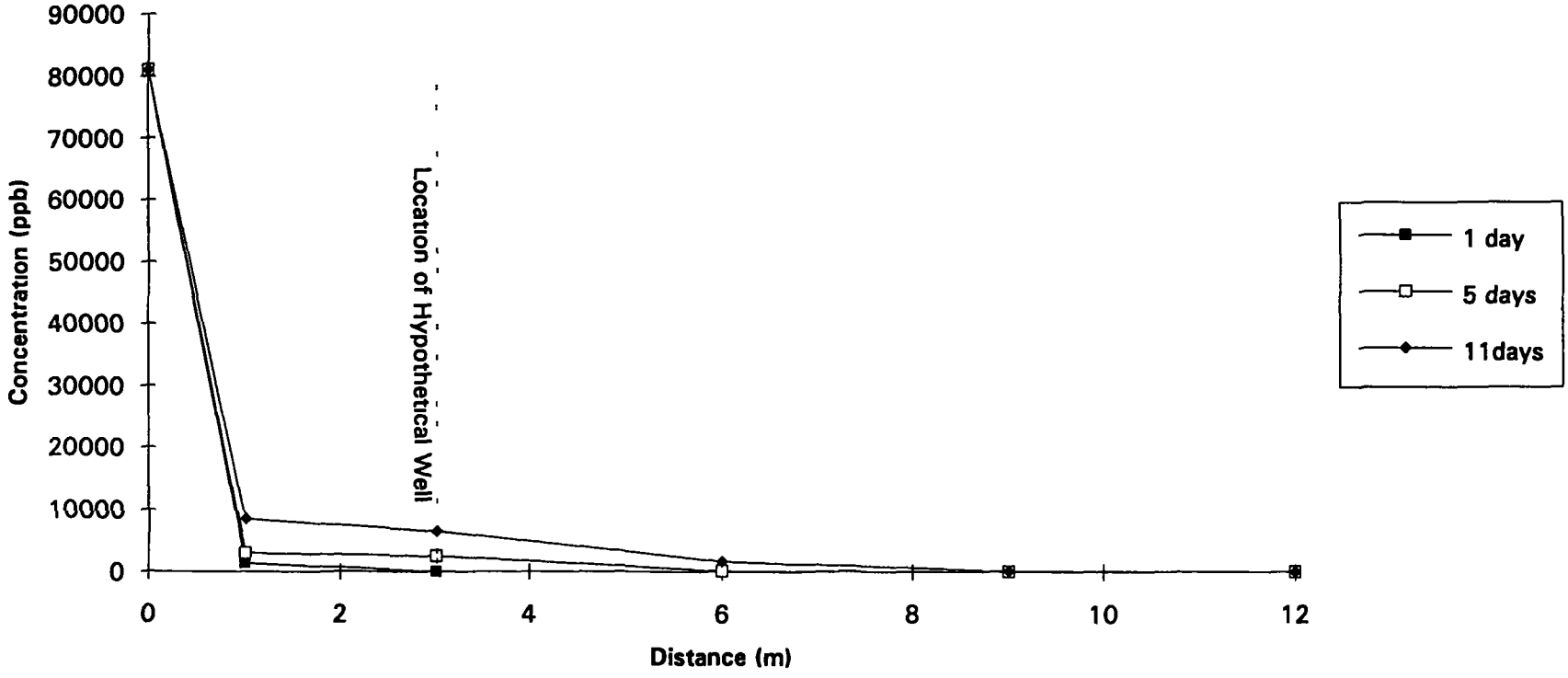

Figure A-32
Benzene Transport in the INT
From INT-11 Area to a Well North of Gulf Pump Road

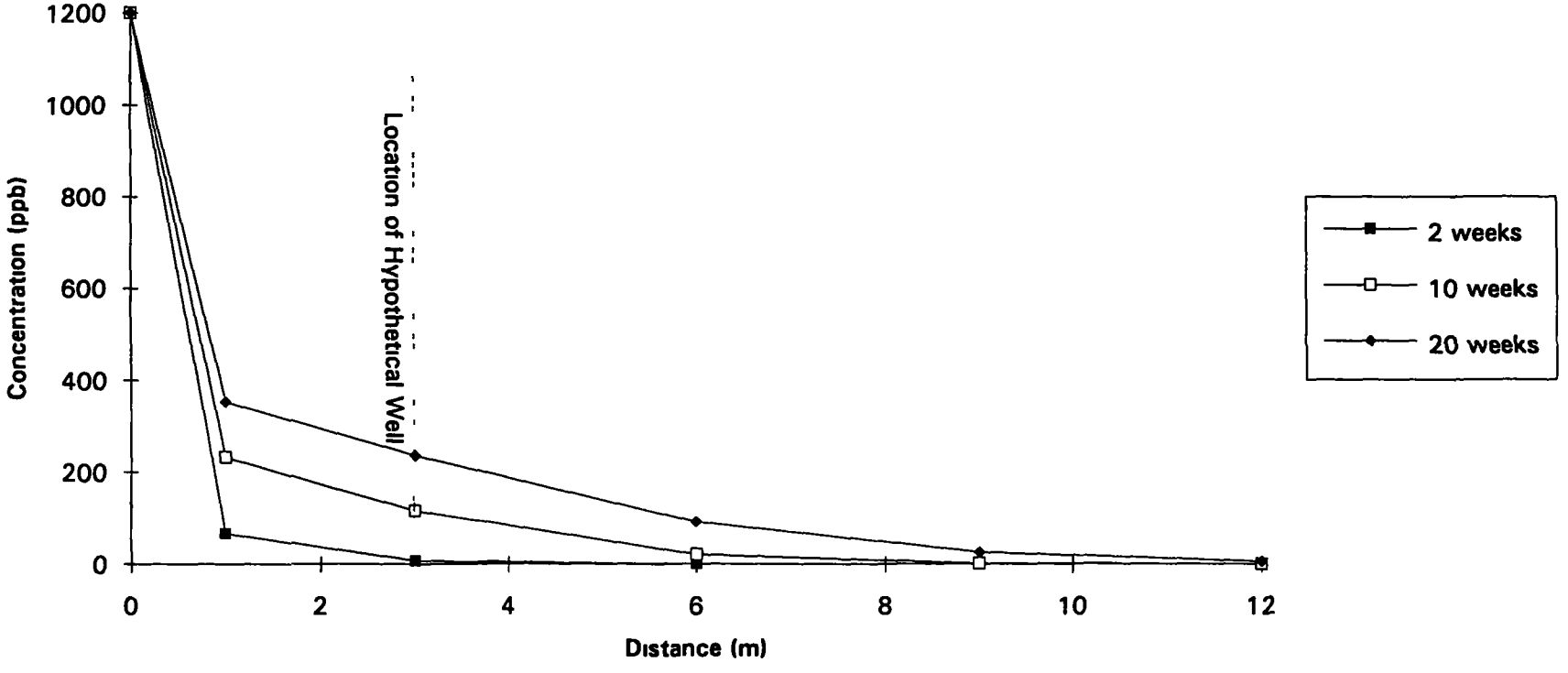

Figure A-33
Vinyl Chloride Transport in the INT
From INT-11 Area to a Well North of Gulf Pump Road

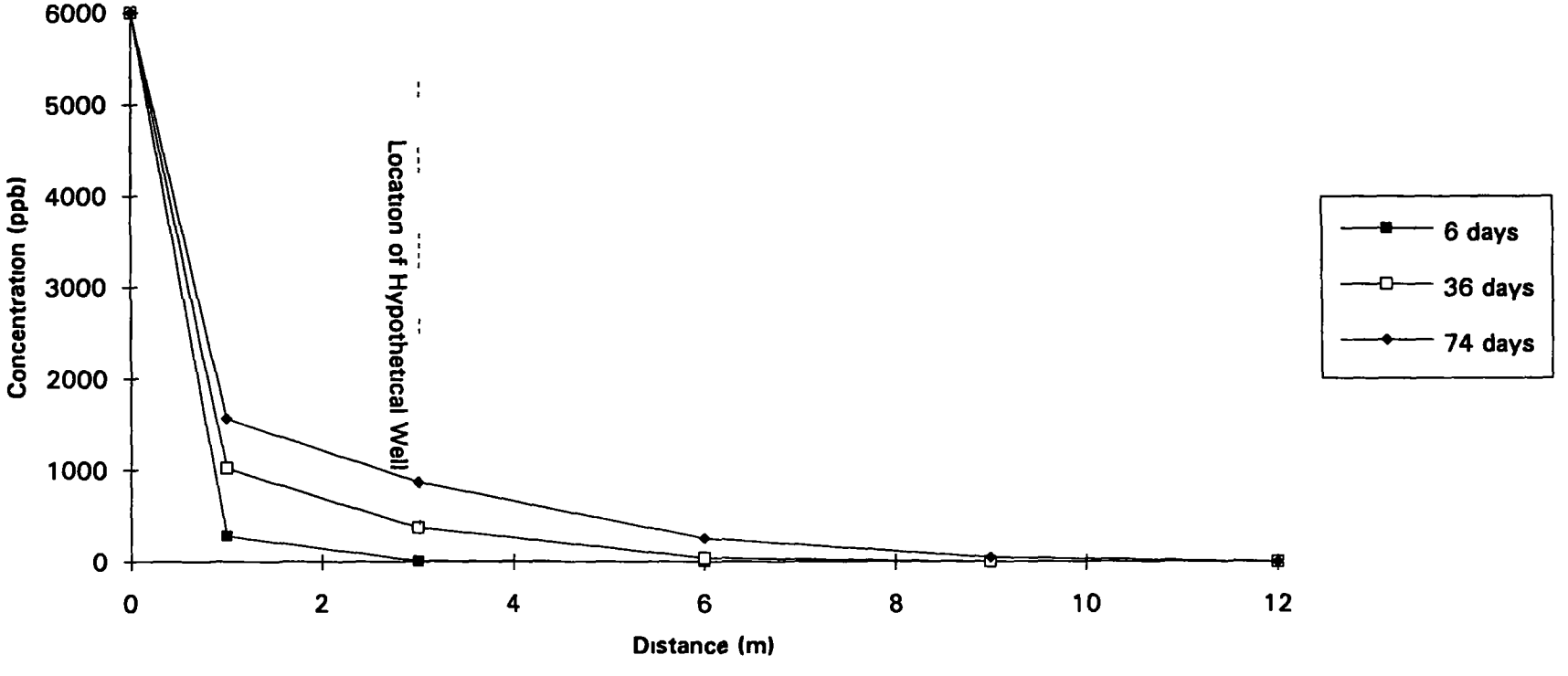

Figure A-34
1,2-DCA Transport in the INT
From INT-11 Area to a Well North of Gulf Pump Road

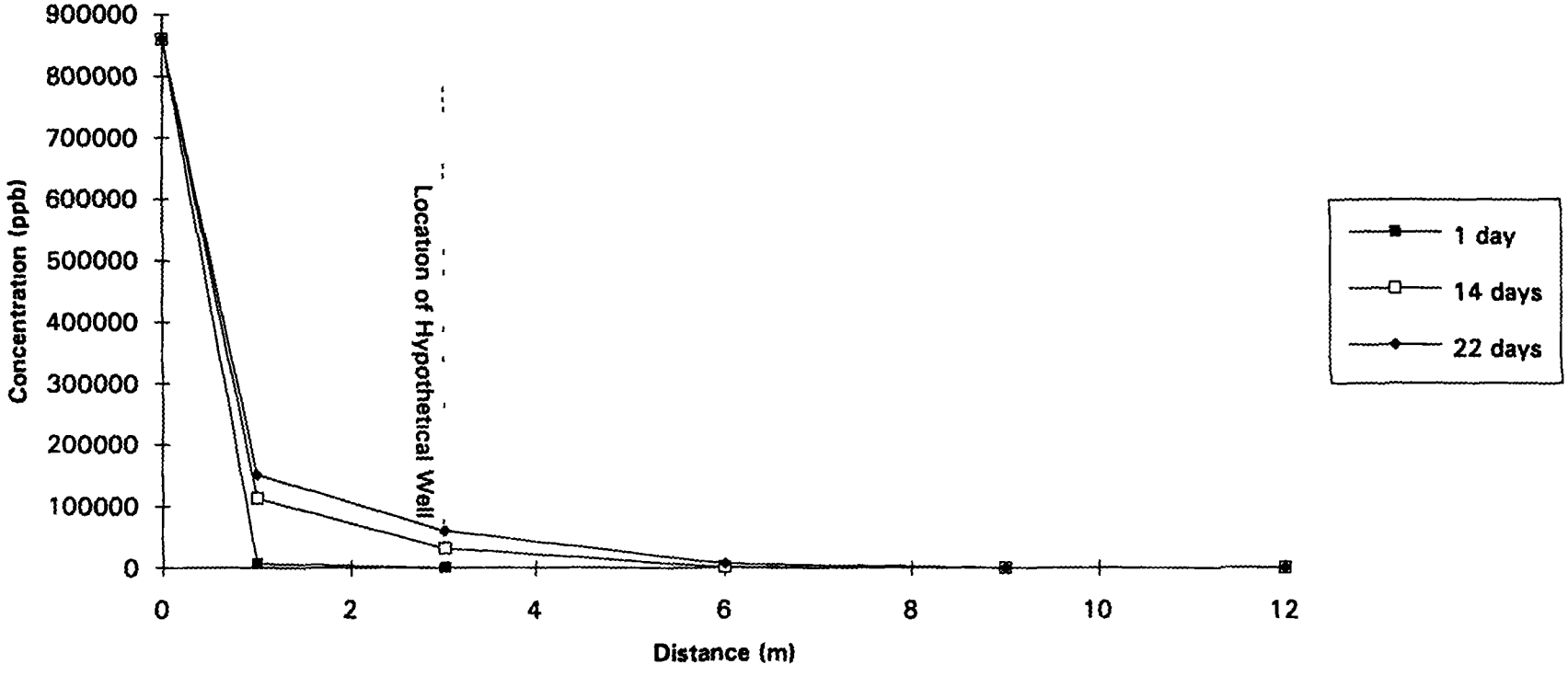

Figure A-35
Chloroform Transport in the INT
From INT-11 Area to a Well North of Gulf Pump Road

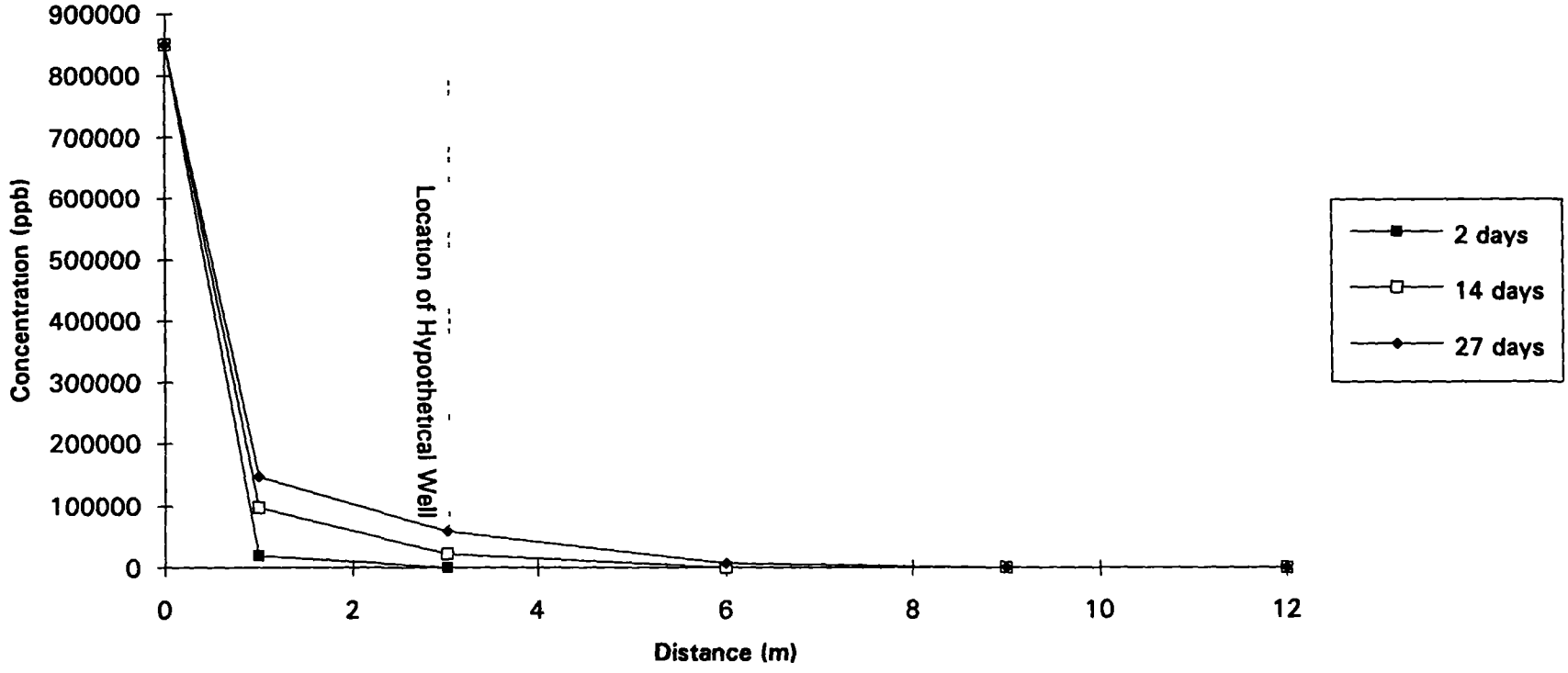

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Table A-10: Transport in the S1-Unit From S1-13 Area to a Well North of Gulf Pump Road

Distance to well north of Gulf Pump Road = 30 m — Concentrations in ppb

Acetone (criteria = 3,500 ppb) — Time to hypothetical domestic well = 3-4 days

Time	Distance						
	m	0	10	20	25	30	35
	ft.	0	33	66	82	98	115
1 day		76036	575	3 54	0	0	0
2 days		76036	2440	31.5	1 99	0 06	0
4 days		76036	8840	900	187	28 9	3 4

Benzene (criteria = 5 ppb) — Time to hypothetical domestic well = 35-36 days

Time	Distance						
	m	0	10	20	25	30	35
	ft.	0	33	66	82	98	115
7 days		1300	8 86	0	0	0	0
14 days		1300	55.8	1 16	0 07	0	0
36 days		1300	260	55 4	19 5	5 64	1 33

Vinyl Chloride (criteria = 2 ppb) — Time to hypothetical domestic well = 19-20 days

Time	Distance						
	m	0	10	20	25	30	35
	ft.	0	33	66	82	98	115
10 days		7278	297	5 67	0 35	0 01	0
14 days		7278	570	32.2	4 44	0 41	0 03
20 days		7278	1010	132	33	6 3	0.92

1,2 DCA (criteria = 5 ppb) — Time to hypothetical domestic well = 9-10 days

Time	Distance						
	m	0	10	20	25	30	35
	ft	0	33	66	82	98	115
5 days		20000	597	6 43	0 27	0	0
7 days		20000	1210	45.3	4 6	0 3	0 01
10 days		20000	2230	218	43 9	6 51	0 7

Chloroform (criteria = 10 ppb) — Time to hypothetical domestic well = 9-10 days

Time	Distance						
	m	0	10	20	25	30	35
	ft.	0	33	66	82	98	115
5 days		131131	2370	9 95	0 21	0	0
7 days		131131	5290	99 3	6 12	2 17	0
10 days		131131	10500	624	88 3	8 52	0 55

Figure A-36
Acetone Transport in the INT
From S1-13 Area to a Well North of Gulf Pump Road

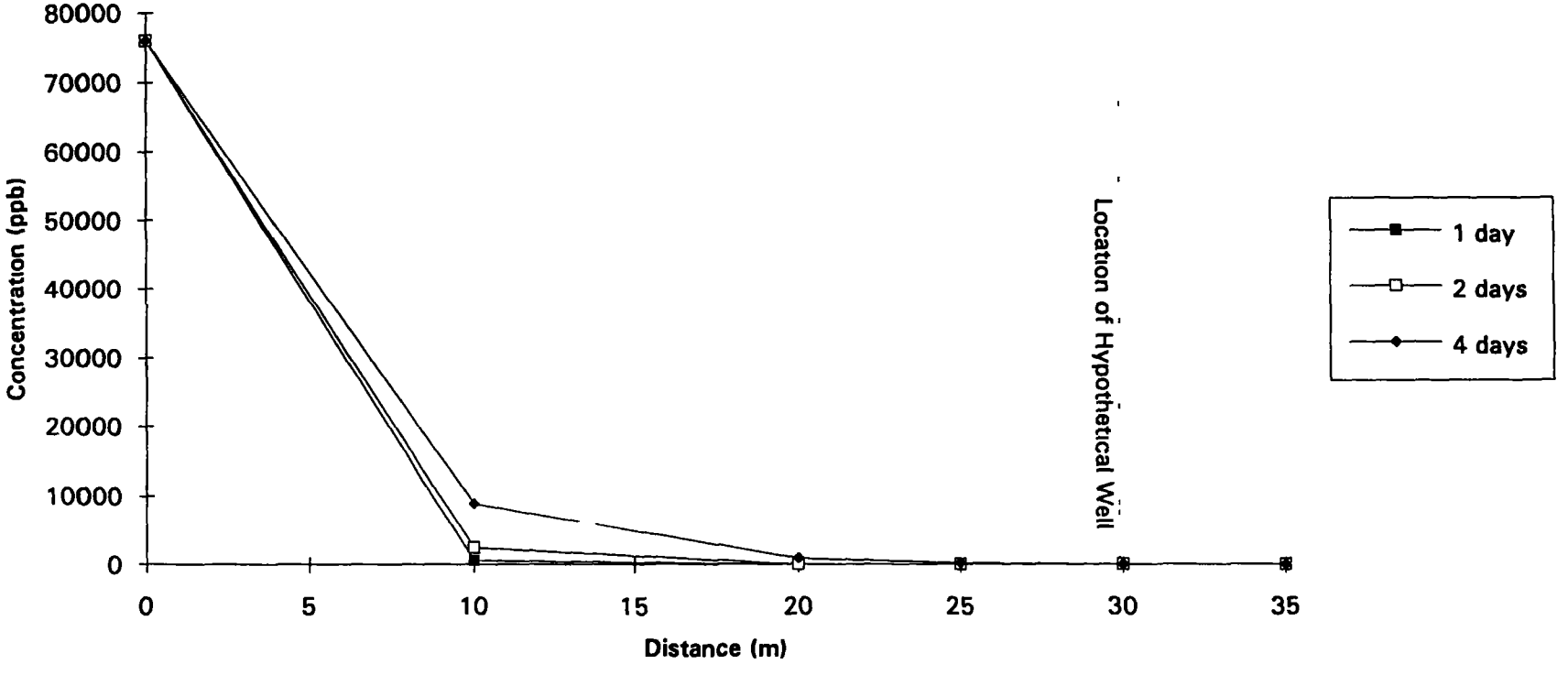


Figure A-37
Benzene Transport in the INT
From S1-13 Area to a Well North of Gulf Pump Road

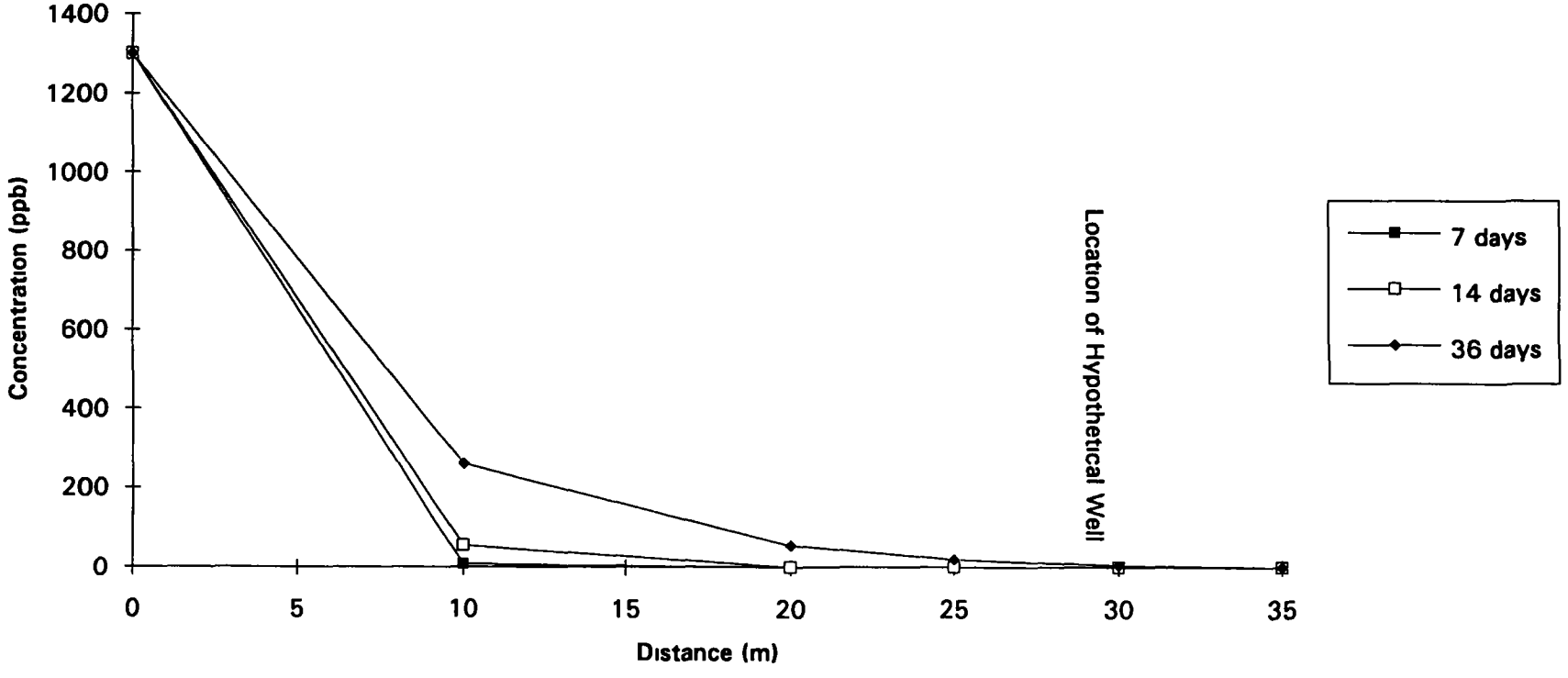


Figure A-38
Vinyl Chloride Transport in the INT
From S1-13 Area to a Well North of Gulf Pump Road

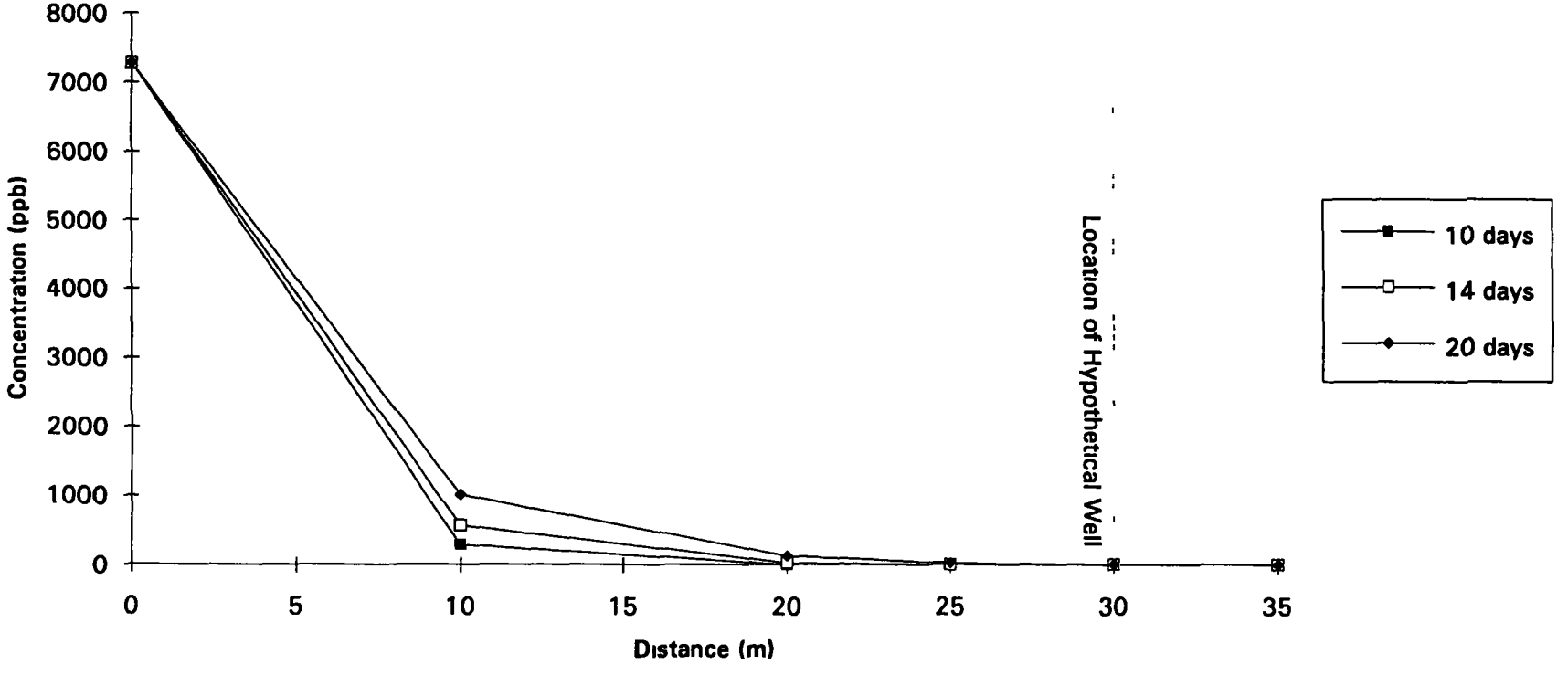


Figure A-39
1,2-DCA Transport in the INT
From S1-13 Area to a Well North of Gulf Pump Road

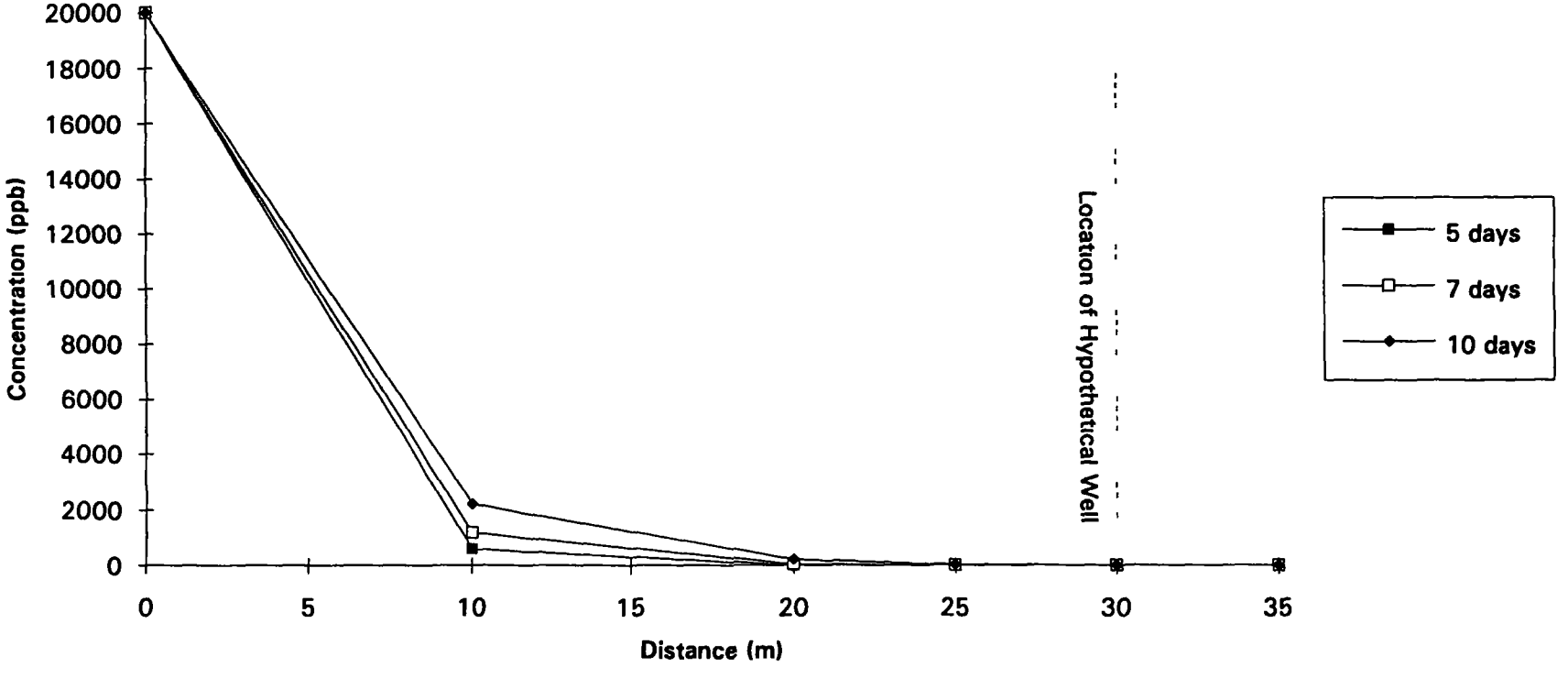
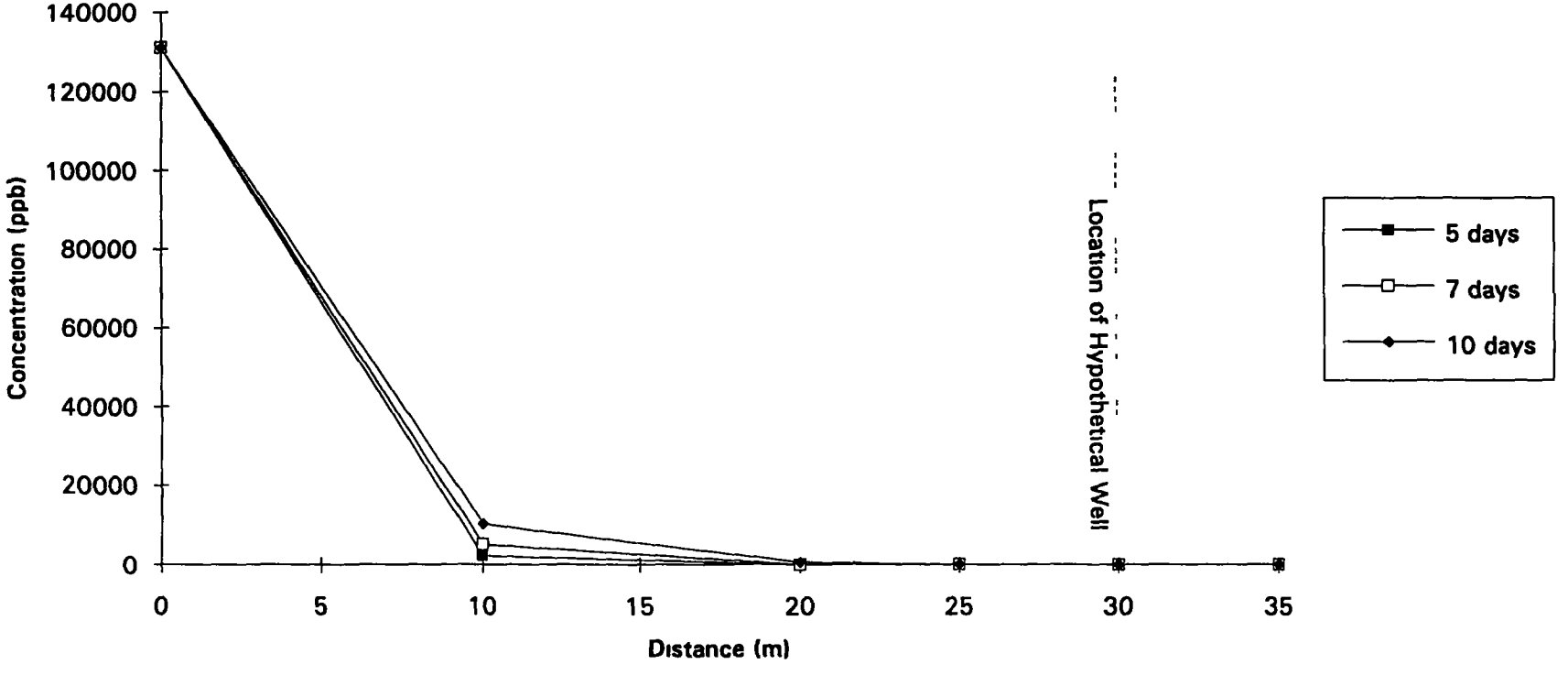


Figure A-40
Chloroform Transport in the INT
From S1-13 Area to a Well North of Gulf Pump Road



BOOKMARK

APPENDIX B

EXPOSURE EQUATIONS AND VARIABLES

TABLE B-1

RESIDENTIAL EXPOSURE: INGESTION OF CHEMICALS IN DRINKING WATER

Equation:

$$\text{Intake (mg/kg-day)} = \frac{CW \times IR \times EF \times ED}{BW \times AT}$$

Where

CW = Chemical Concentration in Water (mg/liter)
IR = Ingestion Rate (liters/day)
EF = Exposure Frequency (days/year)
ED = Exposure Duration (years)
BW = Body Weight (kg)
AT = Averaging Time (period over which exposure is averaged - days)

Variable Values

CW — Site-specific measured or modeled value

IR — 2 liters/day (adult, 90th percentile; EPA 1989d)
1 4 liters/day (adult, average; EPA 1989d)
Age-specific values (EPA 1989d)

EF: — Pathway-specific value (for residents, usually daily - 365 days/year)

ED. — 70 years (lifetime, by convention)
30 years (national upper-bound time (90th percentile) at one residence, EPA 1985a, 1989d)
9 years (national median time (50th percentile) at one residence; EPA 1989d)

BW — 70 kg (adult, average, EPA 1989d)
Age-specific values (EPA 1985a, 1989d)

AT: — Pathway-specific period of exposure for noncarcinogenic effects (i e., ED x 365 days/year), and 70 year lifetime for carcinogenic effects (i e , 70 years x 365 days/year)

TABLE B-2

RESIDENTIAL EXPOSURE: INGESTION OF CHEMICALS IN SURFACE WATER WHILE SWIMMING

Equation.

$$\text{Intake (mg/kg-day)} = \frac{CW \times CR \times ET \times EF \times ED}{BW \times AT}$$

Where:

CW = Chemical Concentration in Water (mg/liter)
CR = Contact Rate (liters/hour)
ET = Exposure Time (hours/event)
EF = Exposure Frequency (events/year)
ED = Exposure Duration (years)
BW = Body Weight (kg)
AT = Averaging Time (period over which exposure is averaged - days)

Variable Values

CW: Site-specific measured or modeled value

CR: 50 ml/hour (EPA 1989d)

ET: Pathway-specific value

EF Pathway-specific value (should consider local climatic conditions [e g , number of days above a given temperature] and age of potentially exposed population)
7 days/year (national average for swimming, USDOI in EPA 1988b, EPA 1989d)

ED 70 years (lifetime, by convention)
30 years (national upper-bound time (90th percentile) at one residence, EPA 1985a, 1989d)
9 years (national median time (50th percentile) at one residence, EPA 1989d)

BW: 70 kg (adult, average, EPA 1989d)
Age-specific values (EPA 1985a, 1989d)

AT Pathway-specific period of exposure for noncarcinogenic effects (i e , ED x 365 days/year), and 70 year lifetime for carcinogenic effects (i e., 70 years x 365 days/year)

TABLE B-3

RESIDENTIAL EXPOSURE: DERMAL CONTACT WITH CHEMICALS IN WATER

Equation

$$\text{Absorbed Dose (mg/kg-day)} = \frac{CW \times SA \times PC \times ET \times EF \times ED \times CF}{BW \times AT}$$

Where

CW = Chemical Concentration in Water (mg/liter)
SA = Skin Surface Area Available for Contact (cm^2)
PC = Chemical-specific Dermal Permeability Constant (cm/hr)
ET = Exposure Time (hours/day)
EF = Exposure Frequency (days/year)
ED = Exposure Duration (years)
CF = Volumetric Conversion Factor for Water (1 liter/1000 cm^3)
BW = Body Weight (kg)
AT = Averaging Time (period over which exposure is averaged - days)

Variable Values

CW Site-specific measured or modeled value

SA: 50th Percentile Total Body Surface Area (m^2) (EPA 1989d, 1985a)

AGE (YRS)	MALE	FEMALE
3 < 6	0 728	0 711
6 < 9	0 931	0 919
9 < 12	1 16	1 16
12 < 15	1 49	1 48
15 < 18	1.75	1 60
Adult	1 94	1 69

50th Percentile Body Part-specific Surface Areas for Males (m^2) (EPA 1989d, 1985a)

AGE(YRS)	ARMS	HANDS	LEGS
3 < 4	0 096	0 040	0 18
6 < 7	0 11	0 041	0 24
9 < 10	0 13	0 057	0 31
Adult	0 23	0 082	0 55

NOTE Values for children were calculated using age-specific body surface areas and the average percentage of total body surface area represented by particular body parts in children, presented in EPA 1985a Values for adults presented in EPA 1989d or calculated from information presented in EPA 1984a Information on surface area of other body parts (e g , head, feet) and for female children and adults also is presented in EPA 1985a, 1989d Differences in body part surface area between sexes is negligible

TABLE B-3 (cont.)

RESIDENTIAL EXPOSURE: DERMAL CONTACT WITH CHEMICALS IN WATER

Variable Values (cont):

PC: Consult open literature for values [Note that use of PC values results in an estimate of absorbed dose]

ET. Pathway-specific value (consider local activity patterns if information is available)
2 6 hrs/day (national average for swimming, USDOI in EPA 1988b, EPA 1989d)

EF: Pathway-specific value (should consider local climatic conditions [e g , number of days above a given temperature] and age of potentially exposed population)
7 days/year (national average for swimming; USDOI in EPA 1988b, EPA 1989d)

ED: 70 years (lifetime, by convention)
30 years (national upper-bound time (90th percentile) at one residence, EPA 1985a, 1989d)
9 years (national median time (50th percentile) at one residence, EPA 1989d)

CF 1 liter/1000 cm^3

BW 70 kg (adult, average; EPA 1989d)
Age-specific values (EPA 1985a, 1989d)

AT· Pathway-specific period of exposure for noncarcinogenic effects (i e , ED x 365 days/year), and 70 year lifetime for carcinogenic effects (i e , 70 years x 365 days/year)

TABLE B-4

RESIDENTIAL EXPOSURE: INHALATION OF AIRBORNE (VAPOR PHASE) CHEMICALS

Equation

$$\text{Intake (mg/kg-day)} = \frac{CA \times IR \times ET \times EF \times ED}{BW \times AT}$$

Where

CA = Chemical Concentration in Air (mg/m^3)
IR = Inhalation Rate (m^3/hour)
ET = Exposure Time (hours/day)
EF = Exposure Frequency (days/year)
ED = Exposure Duration (years)
BW = Body Weight (kg)
AT = Averaging Time (period over which exposure is averaged - days)

Variable Values

CA· Site-specific measured or modeled value

IR
30 m^3/day (adult, suggested upper bound value, EPA 1989d)
20 m^3/day (adult, average, EPA 1989d)
Hourly rates (EPA 1989d)
Age-specific values (EPA 1985a)
Age, sex, and activity based values (EPA 1985a)
0 6 m^3/hr - showering (all age groups, EPA 1989d)

ET *Pathway-specific values (dependent on duration of exposure-related activities)*
12 minutes - showering (90th percentile, EPA 1989d)
7 minutes - showering (50th percentile; EPA 1989d)

EF Pathway-specific value (dependent on frequency of showering or other exposure-related activities)

ED. 70 years (lifetime, by convention)
30 years (national upper-bound time (90th percentile) at one residence, EPA 1985a, 1989d)
9 years (national median time (50th percentile) at one residence, EPA 1989d)

BW. 70 kg (adult, average, EPA 1989d)
Age-specific values (EPA 1985a, 1989d)

AT Pathway-specific period of exposure for noncarcinogenic effects (i e , ED x 365 days/year), and 70 year lifetime for carcinogenic effects (i e , 70 years x 365 days/year)

TABLE B-4 (Continued)

CALCULATION OF EXPOSURE FOR INHALATION OF VAPOR PHASE CHEMICALS DURING SHOWERING

Exposure concentrations and CDI based on inhalation during showering with contaminated groundwater (modified after Foster and Chrostowski, 1987)

$$CA = S \times D = CWd \times FR \times D / SV \quad (1A)$$

$$D = Ds + \exp(-rDt)/r - \exp(r(Ds-Dt))/r \quad (1B)$$

where:

CA = average air concentration during showering (mg/m3)
S = indoor chemical vapor generation rate (ug/m3-min)
FR = shower water flow rate [assumed at 20 L/min]
Ds = duration of shower (min) [assumed at 12 min]
Dt = total time in shower room (min) [assumed at 25 min]
r = air exchange rate (1/min) [assumed at 0 0083 vol/min]
SV = shower room volume (m3) [assumed at 10.5 m3]
CWd = water concentration leaving the shower droplets (ug/L)

$$= CW (1-\exp(-Kal*ts/60d)) \quad (2)$$

CW = water concentration (ug/L)
Kal = mass transfer coefficient (liquid -gas) adjusted for water temp (cm/hr)

$$= 1/(1/kl + (R*T)/(H*kg)) \quad (3)$$

ts = shower droplet drop time (sec) [assumed at 2 secs]
d = shower droplet diameter (mm) [assumed at 1 mm]
kl = liquid - film mass tranfer coefficient (cm/hr)

$$= kl(CO2) \sqrt{[(44/MW)]} \quad (4)$$

kg = gas - film mass tranfer coefficient (cm/hr)

$$= kg(H2O) \sqrt{[(18/MW)]} \quad (5)$$

H = Henry,s Law Constant (atm-m3/mol)
R = gas constant (m3- atm/(mole-degK)
T = temperature (degK)

Intake by inhalation based on showering with contaminated groundwater scenario
Intake (mg/kg-day) = CA*IR*ET*EF*ED/(BW*AT)

where

CA = air concentration (mg/m3)
IR = Inhalation rate (m3/hr)
ET = Exposure time (hrs/day)
EF = Exposure frequency (days/yr)
ED = Exposure duration (yrs)
BW = Body weight (Kg)
AT = Averaging time for exposure effects (days)

APPENDIX B-4

Volatilization of Chemicals During Showering

Potential inhalation exposures to chemicals in groundwater used as a domestic water source were evaluated for a showering scenario, using a model developed by Foster and Chrostowski (1987). This model is based on the rate at which a chemical escapes as a vapor from water droplets produced during showering, and is modeled using mass transfer coefficients The model also assumes a constant ventilation (breathing) rate for an individual. The model provides an estimate of the exposure to volatile chemicals present in the shower (tap) water via inhalation of chemical vapors produced during and after showering. The Foster and Chrostowski model assumes a gradual buildup of chemical vapors in the bathroom during showering and a decrease, or decay, during the additional few minutes an individual is expected to remain in the bathroom after showering.

The parameters and equations used for estimating the rate of vaporization and inhalation exposure are summarized in Table B-4. Two important parameters used in the model are "k_g" and "k_l", the gas- and liquid-film mass transfer coefficients, respectively Foster and Chrostowski (1987) present relationships for estimating these chemical-specific parameters from known k values for water and carbon dioxide. A particularly attractive feature of the Foster and Chrostowski approach is the capability of the model to estimate a total hypothetical inhalation dose to the individual, including the additional dose received during the time from the end of the shower to the time the individual leaves the bathroom. This additional exposure is considered by assuming an exponential decay of chemical vapors following termination of the shower, the air exchange rate, the total duration in the shower room, and the difference between the total duration and the shower time.

This shower model accounts for all factors that are expected to significantly affect the inhalation exposure dose an individual may receive when showering with contaminated domestic water. One of the more important factors is the air exchange rate, r. This parameter accounts for the time-dependent escape of chemical vapors from the bathroom to outside air. Since the bathroom door is assumed to be closed during shower activities, a conservatively small value for r of 0.0083 vol./min. was used to model inhalation doses from chemicals in the groundwater. Use of this value assumes that 0.83 percent (less than 1 percent) of the total volume of air in the bathroom exchanges with outdoor air every minute. Foster and Chrostowski (1987) have pointed out that this value represents an upper bound estimate of the actual air exchange rate. Foster and Chrostowski (1987) suggest a range of 0.5 vol./hr. (0.0083 vol /min.) to 1 5 vol /hr. Therefore, because the air concentration of volatile chemicals in the bathroom generated during showering is inversely related to the air exchange rate, choosing the low end of a range of air exchange rates ensures that the final calculated inhalation doses will be maximized and conservative. This value of 0 0083 vol./min is also consistent with the air exchange rates reported by ASHRAE (1981)

Estimation of the rate of a chemical released into the air during showering was derived from Liss and Slater's (1974) adaptation of the two-layer film model of gas-liquid mass transfer. The two-film boundary theory provides the basis for estimating the overall mass transfer coefficient (K_l) for each chemical of interest. Equation 3 describes the mass transfer rate of a compound at an air-water interface where diffusion may be limited by both liquid- and gas-phase resistances.

The chemical-specific resistances to mass transport for both the liquid and gas phases were calculated from empirical expressions suggested by Foster and Chrostowski (1987) and are expressed in Equations 4 and 5. Values of k_l (20 cm/hr.) and k_g (3,000 cm/hr.), which have been measured for CO_2 and H_2O, respectively (Liss and Slater, 1974), were used to estimate chemical-specific values for these parameters. The molecular weights of 18 and 44 g/mole for H_2O and CO_2, respectively, were used in the equation.

The chemical concentration leaving the shower droplet, C_{wd}, was derived using Equation 2, an integrated rate Equation based on a mass-balance approach. The term K_{al}/60d, combines both the rate transfer and the available interfacial area across which volatilization can occur. The term 1/60d is obtained by multiplying the specific interfacial area for a spherical shower droplet of diameter d, given by the term 6/d, by conversion factors of 1 hr./3600 sec and 10 mm/cm The chemical generation rate in the shower room, S, was then calculated according to Equation 1. The shower room air volume (SV) was set equal to a value of 10.5 m^3. In the absence of more specific information on the shower room air volumes in homes in the vicinity of the French Limited site, this assumed volume gives a reasonable estimate of the inhalation exposures an individual may hypothetically receive due to showering with contaminated groundwater.

The Foster and Chrostowski model (1987) was used to estimate chemical air concentrations in the shower room during and after the shower. This model can be expressed as a differential equation describing the rate of change of the indoor chemical concentration with time:

$$dC_a/dt = rC_a + S \qquad (7)$$

where:

C_a = indoor chemical air concentration (ug/m^3)

r = air exchange rate (min^{-1}), and

All other parameters have been previously defined.

Some of the values for the parameters used in the model were derived from chemical-specific sources and as such, can be obtained from the literature or can be calculated according to accepted mathematical relationships. Other parameters were derived from exposure-specific sources

TABLE B-5

RESIDENTIAL EXPOSURE: FOOD PATHWAY - INGESTION OF CONTAMINATED FISH AND SHELLFISH

Equation

$$\text{Intake (mg/kg-day)} = \frac{CF \times IR \times FI \times EF \times ED}{BW \times AT}$$

Where

CF	=	Chemical Concentration in Fish (mg/kg)
IR	=	Ingestion Rate (kg/meal)
FI	=	Fraction Ingested from Contaminated Source (unitless)
EF	=	Exposure Frequency (meals/year)
ED	=	Exposure Duration (years)
BW	=	Body Weight (kg)
AT	=	Averaging Time (period over which exposure is averaged - days)

Variable Values

CF. Site-specific measured or modeled value

IR: 0 284 kg/meal (95th percentile for fin fish, Pao *et al* 1982)
0 113 kg/meal (50th percentile for fin fish, Pao *et al* 1982)

132 g/day (95th percentile daily intakes averaged over three days for consumers of fin fish, Pao *et al.* 1982)
38 g/day (50th percentile daily intake, averaged over three days for consumers of fin fish; Pao *et al* 1982)
6 5 g/day (daily intake averaged over a year, EPA 1989d
NOTE Daily intake values should be used in conjuction with an exposure frequency of 365 days/year)
Specific values for age, sex, race, region and fish species are available (EPA 1989d, 1989h)

FI Pathway-specific value (should consider local usage patterns)

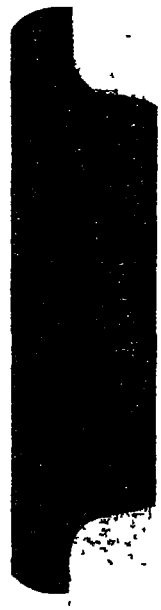
EF Pathway-specific value (should consider local population patters if information is available)
48 day/year (average per capita for fish and shellfish, EPA Tolerance Assessment System in EPA 1989h)

ED: 70 years (lifetime, by convention)
30 years (national upper-bound time (90th percentile) at one residence, EPA 1985a, 1989d)
9 years (national median time (50th percentile) at one residence, EPA 1989d)

BW 70 kg (adult, average, EPA 1989d)
Age-specific values (EPA 1985a, 1989d)

AT Pathway-specific period of exposure for noncarcinogenic effects (i e , ED x 365 days/year), and 70 year lifetime for carcinogenic effects (i e , 70 years x 365 days/year)

BOOKMARK



APPENDIX C

SUPPLEMENTAL DNAPL ANALYSES

11/18/93

Summary of Analytical Results

Date received: 17-DEC-1993 Customer: FMC ,INC. Job name: H93-12.159

		Samples		
Chester LabNet ID		159-001	159-002	159-003
Sampling Point		QA QC	X	X
Date Sampled		23-NOV-1993	23-NOV-1993	22-NOV-1993
Customer ID		LAB BLANK	S04J000202	S04J000203
		NA	NA	NA
Parameters	Units			
Total Organic Halogens (Solid)	mg/Kg	<20.0	818000	340000
Analyst: DH				
Date/Time: 12/23/93				
Dilution: 1.0				
Total Organic Carbon (Solid)	mg/Kg	<50.0	88400	32100
Analyst: DH				
Date/Time: 12/23/93				
Dilution: 1.0				

085569

INST ID: 4020 SAMPLE NUMBER: S04J000202

ORGANICS ANALYSIS DATA SHEET

BORATORY NAME: CHESTER LABNET
LAB SAMPLE ID NO.: 931215902
SAMPLE MATRIX: SOIL
DATA RELEASE AUTHORIZED BY: ..... DATE SAMPLE RECEIVED: 12/17/93

VOLATILES

CONCENTRATION: MED DATAFILE: RU12159V02
DATE ANALYZED: 12/29/93 DILUTION FACTOR: 250.00

	COMPOUND	DETECTION LIMIT (MILLIGRAMS / KG)	AMOUNT FOUND
C010	CHLOROMETHANE	2500 U	
C015	BROMOMETHANE	2500 U	
C020	VINYL CHLORIDE	2500 U	
C025	CHLOROETHANE	2500	2300 J
C030	METHYLENE CHLORIDE	1250	1600
C035	ACETONE	2500 U	
C040	CARBON DISULFIDE	1250 U	
C045	1,1-DICHLOROETHENE	1250	2300
C050	1,1-DICHLOROETHANE	1250	5000
C053	1,2-DICHLOROETHENE (TOTAL)	1250	47000
C060	CHLOROFORM	1250	180000
C065	1,2-DICHLOROETHANE	1250	130000
C110	2-BUTANONE	2500 U	
C115	1,1,1-TRICHLOROETHANE	1250 U	
C120	CARBON TETRACHLORIDE	1250	20000
C125	VINYL ACETATE	2500 U	
C130	BROMODICHLOROMETHANE	1250 U	
C140	1,2-DICHLOROPROPANE	1250 U	
C143	CIS-1,3-DICHLOROPROPENE	1250 U	
C150	TRICHLOROETHENE	1250	5200
C155	DIBROMOCHLOROMETHANE	1250 U	
C160	1,1,2-TRICHLOROETHANE	1250 U	
C165	BENZENE	1250 U	
C172	TRANS-1,3-DICHLOROPROPENE	1250 U	
C175	2-CHLOROETHYLVINYLETHER	2500 U	
C180	BROMOFORM	1250 U	
C205	4-METHYL-2-PENTANONE	2500 U	
C210	2-HEXANONE	2500 U	
C220	TETRACHLOROETHENE	1250 U	
C225	1,1,2,2-TETRACHLOROETHANE	1250 U	
C230	TOLUENE	1250 U	
C235	CHLOROBENZENE	1250 U	
C240	ETHYLBENZENE	1250	710 J
C245	STYRENE	1250 U	
C250	XYLENES (TOTAL)	1250	3300

U = UNDETECTED AT THE LISTED DETECTION LIMIT
J = COMPOUND IS PRESENT, BUT BELOW THE LISTED DETECTION LIMIT

INST ID: 4020 CHESTER DC # ---- 8

SAMPLE NUMBER: S04J000202

ORGANICS ANALYSIS DATA SHEET - PAGE 4

LABORATORY NAME: CHESTER LABNET CASE NO.: ---

QC REPORT NO.: ..... ANALYST: PFC DATAFILE: RU12159V0:

B. TENTATIVELY IDENTIFIED COMPOUNDS

CAS #	VOLATILE COMPOUND NAMES	SCAN#	PURITY	AMOUNT MG/KG
	UNKNOWN-DOESN'T MATCH ANY LIBRARY SPECTRA	325		310000
	UNKNOWN-DOESN'T MATCH ANY LIBRARY SPECTRA	533		68000
	UNKNOWN-DOESN'T MATCH ANY LIBRARY SPECTRA	635		4200
	UNKNOWN-DOESN'T MATCH ANY LIBRARY SPECTRA	728		2300
	ALIPHATIC HYDROCARBON	743		29000
	UNKNOWN-DOESN'T MATCH ANY LIBRARY SPECTRA	761		2400
	UNKNOWN-DOESN'T MATCH ANY LIBRARY SPECTRA	786		23000

J = ESTIMATED VALUE - A 1:1 RESPONSE FACTOR IS ASSUMED

85571

INST ID: 4020 SAMPLE NUMBER: S04J000202 (DL)

ORGANICS ANALYSIS DATA SHEET

LABORATORY NAME: CHESTER LABNET
LAB SAMPLE ID NO.: 931215902A
SAMPLE MATRIX: SOIL
DATA RELEASE AUTHORIZED BY: ..... DATE SAMPLE RECEIVED: 12/17/93

VOLATILES

CONCENTRATION: MED DATAFILE: RU12159V02A
DATE ANALYZED: 12/29/93 DILUTION FACTOR: 5000.00

	COMPOUND	DETECTION LIMIT (MILLIGRAMS / KG)	AMOUNT FOUND
C010	CHLOROMETHANE	50000 U	
C015	BROMOMETHANE	50000 U	
C020	VINYL CHLORIDE	50000 U	
C025	CHLOROETHANE	50000 U	
C030	METHYLENE CHLORIDE	25000 U	
C035	ACETONE	50000 U	
C040	CARBON DISULFIDE	25000 U	
C045	1,1-DICHLOROETHENE	25000 U	
C050	1,1-DICHLOROETHANE	25000 U	
C053	1,2-DICHLOROETHENE (TOTAL)	25000	80000
C060	CHLOROFORM	25000	220000
C065	1,2-DICHLOROETHANE	25000	140000
C110	2-BUTANONE	50000 U	
C115	1,1,1-TRICHLOROETHANE	25000 U	
C120	CARBON TETRACHLORIDE	25000	190000
C125	VINYL ACETATE	50000 U	
C130	BROMODICHLOROMETHANE	25000 U	
C140	1,2-DICHLOROPROPANE	25000 U	
C143	CIS-1,3-DICHLOROPROPENE	25000 U	
C150	TRICHLOROETHENE	25000 U	
C155	DIBROMOCHLOROMETHANE	25000 U	
C160	1,1,2-TRICHLOROETHANE	25000 U	
C165	BENZENE	25000 U	
C172	TRANS-1,3-DICHLOROPROPENE	25000 U	
C175	2-CHLOROETHYLVINYLETHER	50000 U	
C180	BROMOFORM	25000 U	
C205	4-METHYL-2-PENTANONE	50000 U	
C210	2-HEXANONE	50000 U	
C220	TETRACHLOROETHENE	25000 U	
C225	1,1,2,2-TETRACHLOROETHANE	25000 U	
C230	TOLUENE	25000 U	
C235	CHLOROBENZENE	25000 U	
C240	ETHYLBENZENE	25000 U	
C245	STYRENE	25000 U	
C250	XYLENES (TOTAL)	25000 U	

U = UNDETECTED AT THE LISTED DETECTION LIMIT
J = COMPOUND IS PRESENT, BUT BELOW THE LISTED DETECTION LIMIT

000005

INST ID: 4020 CHESTER DC # ---- 8

SAMPLE NUMBER: S04J000202

ORGANICS ANALYSIS DATA SHEET - PAGE 4

LABORATORY NAME: CHESTER LABNET CASE NO.: ---

GC REPORT NO.: ..... ANALYST: PFC DATAFILE: RU12159V02

B. TENTATIVELY IDENTIFIED COMPOUNDS

CAS #	VOLATILE COMPOUND NAMES	SCAN#	PURITY	AMOUNT
				UG/KG
	UNKNOWN-DOESN'T MATCH ANY LIBRARY SPECTRA	530		41000
	UNKNOWN-DOESN'T MATCH ANY LIBRARY SPECTRA	552		49000
	UNKNOWN-DOESN'T MATCH ANY LIBRARY SPECTRA	682		140000
	UNKNOWN-DOESN'T MATCH ANY LIBRARY SPECTRA	702		56000
	UNKNOWN-DOESN'T MATCH ANY LIBRARY SPECTRA	776		600000

J = ESTIMATED VALUE - A 1:1 RESPONSE FACTOR IS ASSUMED

INST ID: 4530 SAMPLE NUMBER: 304J000202

ORGANICS ANALYSIS DATA SHEET -

ABORATORY NAME: CHESTER LABNET
LAB SAMPLE ID NO.: 931215902
SAMPLE MATRIX: SOIL
DATA RELEASE AUTHORIZED BY: DATE SAMPLE RECEIVED: 12/17/93

SEMIVOLATILES

CONCENTRATION: LOW DATAFILE: 4U12159C02
DATE EXTRACTED: 12/28/93
DATE ANALYZED: 01/29/94

	COMPOUND	DETECTION LIMIT (MILLIGRAMS / KG)	AMOUNT FOUND	
C315	PHENOL	1000 U		
C325	BIS(2-CHLOROETHYL)ETHER	1000 U		
C330	2-CHLOROPHENOL	1000 U		
C335	1,3-DICHLOROBENZENE	1000 U		
C340	1,4-DICHLOROBENZENE	1000 U		
C345	BENZYL ALCOHOL	1000 U		
C350	1,2-DICHLOROBENZENE	1000 U		
C355	2-METHYLPHENOL	1000 U		
C357	2,2'-OXYBIS(1-CHLOROPROPANE)	1000 U		
C365	4-METHYLPHENOL	1000 U		
C370	N-NITROSODIPROPYLAMINE	1000 U		
C375	HEXACHLOROETHANE	1000	33000	*
C410	NITROBENZENE	1000 U		
C415	ISOPHORONE	1000 U		
C420	2-NITROPHENOL	1000 U		
C425	2,4-DIMETHYLPHENOL	1000 U		
C430	BENZOIC ACID	5000 U		
C435	BIS(2-CHLOROETHOXY)METHANE	1000 U		
C440	2,4-DICHLOROPHENOL	1000 U		
C445	1,2,4-TRICHLOROBENZENE	1000	940	J
C450	NAPHTHALENE	1000	4700	
C455	4-CHLOROANILINE	1000 U		
C460	HEXACHLOROBUTADIENE	1000	230000	*
C465	P-CHLORO-M-CRESOL	1000 U		
C470	2-METHYLNAPHTHALENE	1000	1600	
C510	HEXACHLOROCYCLOPENTADIENE	1000 U		
C515	2,4,6-TRICHLOROPHENOL	1000 U		
C520	2,4,5-TRICHLOROPHENOL	5000 U		
C525	2-CHLORONAPHTHALENE	1000 U		
C530	2-NITROANILINE	5000 U		
C535	DIMETHYL PHTHALATE	1000 U		
C540	ACENAPHTHYLENE	1000	64	J
C545	3-NITROANILINE	5000 U		
C550	ACENAPHTHENE	1000	2000	
C555	2,4-DINITROPHENOL	5000 U		
C560	4-NITROPHENOL	5000 U		
C565	DIBENZOFURAN	1000	1200	
C570	2,4-DINITROTOLUENE	1000 U		
C543	2,6-DINITROTOLUENE	1000 U		

CHESTER LABNET DC # --- 8

SAMPLE NUMBER: S04J000202

SEMIVOLATILE ORGANICS ANALYSIS DATA SHEET, CONTINUED

DATAFILE: 4U12159C02

	COMPOUND	DETECTION LIMIT (MILLIGRAMS / KG)	AMOUNT FOUND
C580	DIETHYL PHTHALATE	1000 U	
C585	4-CHLOROPHENYL PHENYL ETHER	1000 U	
C590	FLUORENE	1000	1900
C595	4-NITROANILINE	5000 U	
C610	4,6-DINITRO-2-METHYLPHENOL	5000 U	
C615	N-NITROSODIPHENYLAMINE	1000 U	
C625	4-BROMOPHENYL PHENYL ETHER	1000 U	
C630	HEXACHLOROBENZENE	1000	3700
C635	PENTACHLOROPHENOL	5000 U	
C640	PHENANTHRENE	1000	3300
C645	ANTHRACENE	1000	160 J
C650	DI-N-BUTYL PHTHALATE	1000 U	
C655	FLUORANTHENE	1000	880 J
C715	PYRENE	1000	910 J
C720	BUTYL BENZYL PHTHALATE	1000 U	
C725	3,3'-DICHLOROBENZIDINE	2000 U	
C730	BENZO(A)ANTHRACENE	1000	170 J
C745	BIS(2-ETHYLHEXYL)PHTHALATE	1000 U	
C740	CHRYSENE	1000	160 J
C760	DI-N-OCTYL PHTHALATE	1000 U	
C765	BENZO(B)FLUORANTHENE	1000	76 J
C770	BENZO(K)FLUORANTHENE	1000 U	
C775	BENZO(A)PYRENE	1000 U	
C780	INDENO(1,2,3-CD)PYRENE	1000 U	
C785	DIBENZO(A,H)ANTHRACENE	1000 U	
C790	BENZO(GHI)PERYLENE	1000 U	

U = UNDETECTED AT THE LISTED DETECTION LIMIT
J = COMPOUND IS PRESENT, BUT BELOW THE LISTED DETECTION LIMIT
* = AMOUNT TAKEN FROM 1:5000 CORRECTION FACTOR RUN

SAMPLE: 804J000202

ORGANICS ANALYSIS DATA SHEET - PAGE 5

LABORATORY NAME: CHESTER LABNET CASE NO.: ---

ANALYST: JZ DATAFILE: 4U12159C02

B. TENTATIVELY IDENTIFIED COMPOUNDS

CAS #	SEMIVOLATILE COMPOUND NAMES	SCAN#	PURITY	AMOUNT
				MG/K(
76-01-7	ETHANE, PENTACHLORO-	342	923	1300
	1,3-BUTADIENE, 1,1,3,4-TETRACHLORO-	466		4200
	CHLORINATED HYDROCARBON COMPOUND	505		5900
	CHLORINATED HYDROCARBON COMPOUND	533		12000
	CHLORINATED HYDROCARBON COMPOUND	542		7100
	CHLORINATED HYDROCARBON COMPOUND	649		610
90120	NAPHTHALENE, 1-METHYL-	667	933	1100
	BENZENE, TETRACHLORO	676		1300
4994-16-5	BENZENE, 3-CYCLOHEXEN-1-YL-	695	918	1400
	BENZENE, TETRACHLORO	716		660
	POLYAROMATIC HYDROCARBON	723		800
608-93-5	BENZENE, PENTACHLORO-	821	890	3000
	UNKNOWN-DOESN'T MATCH ANY LIBRARY SPECTRA	891		9300
	UNKNOWN-DOESN'T MATCH ANY LIBRARY SPECTRA	1153		290
	AROMATIC COMPOUND	1268		360

ESTIMATED VALUE - A 1:1 RESPONSE FACTOR IS ASSUMED

485576

Chester LabNet - HOUSTON

Reported on : 13-JAN-1994

Client Name	: FRENCH LIMITED	Work Order	: H93-12.159
Sample ID	: CAP0110-041	Date Collected	: 23-NOV-1993
Sample Name	: H93-12.159-002 1/100	Matrix	: SOIL
Project No.	: S04J	Date Received	: 17-DEC-1993
Client ID	: S04J0002 02	Date Extracted	: 28-DEC-1993
		Checked by	: MJM

Organic Analysis Data Sheet
Compounds Analysis by SW846 Method 8080

Date Analysed : 11-JAN-1994 19:50 Dilution Factor : 100.000
Analyzed by : 8388656

Cas #	Compound	Detection Limits	Detected Conc. ug/kg	
12674-11-2	AROCLOR-1016	50000	50000	U
11104-28-2	AROCLOR-1221	50000	50000	U
11141-16-5	AROCLOR-1232	50000	50000	U
53469-21-9	AROCLOR-1242	50000	50000	U
12672-29-6	AROCLOR-1248	50000	50000	U
11097-69-1	AROCLOR-1254	50000	50000	U
11096-82-5	AROCLOR-1260	50000	50000	U
	TOTAL PCBS *	50000	50000	U

* = Total PCBs calculated as found AR 1242.
U = Undetected at the Listed Detection Limit .
J = Compound is present, but below the Detection Limit.
B = Compound is also found in Blank.

··85577

INST ID: 4020 SAMPLE NUMBER: S04J000203

ORGANICS ANALYSIS DATA SHEET

3ORATORY NAME: CHESTER LABNET
LAB SAMPLE ID NO.: 931215903
SAMPLE MATRIX: SOIL
DATA RELEASE AUTHORIZED BY: ..... DATE SAMPLE RECEIVED: 12/17/93

VOLATILES

CONCENTRATION: MED DATAFILE: RU12159V03
DATE ANALYZED: 12/29/93 DILUTION FACTOR: 2000.00

	COMPOUND	DETECTION LIMIT (MILLIGRAMS / KG)	AMOUNT FOUND
C010	CHLOROMETHANE	20000 U	
C015	BROMOMETHANE	20000 U	
C020	VINYL CHLORIDE	20000 U	
C025	CHLOROETHANE	20000 U	
C030	METHYLENE CHLORIDE	10000 U	
C035	ACETONE	20000 U	
C040	CARBON DISULFIDE	10000 U	
C045	1,1-DICHLOROETHENE	10000 U	
C050	1,1-DICHLOROETHANE	10000 U	
C053	1,2-DICHLOROETHENE (TOTAL)	10000	15000
C060	CHLOROFORM	10000	28000
C065	1,2-DICHLOROETHANE	10000	19000
C110	2-BUTANONE	20000 U	
C115	1,1,1-TRICHLOROETHANE	10000 U	
C120	CARBON TETRACHLORIDE	10000	10000
C125	VINYL ACETATE	20000 U	
C130	BROMODICHLOROMETHANE	10000	11000
C140	1,2-DICHLOROPROPANE	10000 U	
C143	CIS-1,3-DICHLOROPROPENE	10000 U	
C150	TRICHLOROETHENE	10000	26000
C155	DIBROMOCHLOROMETHANE	10000 U	
C160	1,1,2-TRICHLOROETHANE	10000 U	
C165	BENZENE	10000 U	
C172	TRANS-1,3-DICHLOROPROPENE	10000 U	
C175	2-CHLOROETHYLVINYLETHER	20000 U	
C180	BROMOFORM	10000 U	
C205	4-METHYL-2-PENTANONE	20000 U	
C210	2-HEXANONE	20000 U	
C220	TETRACHLOROETHENE	10000 U	
C225	1,1,2,2-TETRACHLOROETHANE	10000 U	
C230	TOLUENE	10000 U	
C235	CHLOROBENZENE	10000 U	
C240	ETHYLBENZENE	10000 U	
C245	STYRENE	10000 U	
C250	XYLENES (TOTAL)	10000 .. .	8600 J

U = UNDETECTED AT THE LISTED DETECTION LIMIT
J = COMPOUND IS PRESENT, BUT BELOW THE LISTED DETECTION LIMIT

INST ID: 4020 CHESTER DC # ---- 8

SAMPLE NUMBER: 804J000203

ORGANICS ANALYSIS DATA SHEET - PAGE 4

LABORATORY NAME: CHESTER LABNET CASE NO.: ---

QC REPORT NO.: ..... ANALYST: PFC DATAFILE: RU12159V0:

B. TENTATIVELY IDENTIFIED COMPOUNDS

CAS #	VOLATILE COMPOUND NAMES	SCAN#	PURITY	AMOUNT
				MG/K(
	UNKNOWN-DOESN'T MATCH ANY LIBRARY SPECTRA	320		18000
	UNKNOWN-DOESN'T MATCH ANY LIBRARY SPECTRA	360		100000
	UNKNOWN-DOESN'T MATCH ANY LIBRARY SPECTRA	379		170000
	UNKNOWN-DOESN'T MATCH ANY LIBRARY SPECTRA	396		420000
	UNKNOWN-DOESN'T MATCH ANY LIBRARY SPECTRA	412		590000
	UNKNOWN-DOESN'T MATCH ANY LIBRARY SPECTRA	441		130000
	UNKNOWN-DOESN'T MATCH ANY LIBRARY SPECTRA	454		46000
	ALIPHATIC HYDROCARBON	501		19000
	UNKNOWN-DOESN'T MATCH ANY LIBRARY SPECTRA	533		120000
	CYCLIC ALIPHATIC COMPOUND	564		11000
	UNKNOWN-DOESN'T MATCH ANY LIBRARY SPECTRA	582		12000
	ALIPHATIC HYDROCARBON	589		22000
	ALIPHATIC HYDROCARBON	636		82000
	ALIPHATIC HYDROCARBON	681		30000
	UNKNOWN-DOESN'T MATCH ANY LIBRARY SPECTRA	690		54000
	AROMATIC COMPOUND	699		19000
	ALIPHATIC HYDROCARBON	727		17000
	ALIPHATIC HYDROCARBON	762		120000
	UNKNOWN-DOESN'T MATCH ANY LIBRARY SPECTRA	790		37000

INST ID: 4530 SAMPLE NUMBER: S04J000203

ORGANICS ANALYSIS DATA SHEET -

LABORATORY NAME: CHESTER LABNET
LAB SAMPLE ID NO.: 931215903
SAMPLE MATRIX: SOIL
DATA RELEASE AUTHORIZED BY: ..... DATE SAMPLE RECEIVED: 12/17/93

SEMIVOLATILES

CONCENTRATION: LOW DATAFILE: 4U12159C03
DATE EXTRACTED: 12/28/93
DATE ANALYZED: 01/29/94

	COMPOUND	DETECTION LIMIT (MILLIGRAMS / KG)	AMOUNT FOUND	
C315	PHENOL	1000 U		
C325	BIS(2-CHLOROETHYL)ETHER	1000 U		
C330	2-CHLOROPHENOL	1000 U		
C335	1,3-DICHLOROBENZENE	1000 U		
C340	1,4-DICHLOROBENZENE	1000 U		
C345	BENZYL ALCOHOL	1000 U		
C350	1,2-DICHLOROBENZENE	1000 U		
C355	2-METHYLPHENOL	1000 U		
C357	2,2'-OXYBIS(1-CHLOROPROPANE)	1000 U		
C365	4-METHYLPHENOL	1000 U		
C370	N-NITROSODIPROPYLAMINE	1000 U		
C375	HEXACHLOROETHANE	1000	4400	
C410	NITROBENZENE	1000 U		
C415	ISOPHORONE	1000 U		
C420	2-NITROPHENOL	1000 U		
C425	2,4-DIMETHYLPHENOL	1000 U		
C430	BENZOIC ACID	5000 U		
C435	BIS(2-CHLOROETHOXY)METHANE	1000 U		
C440	2,4-DICHLOROPHENOL	1000 U		
C445	1,2,4-TRICHLOROBENZENE	1000	180	J
C450	NAPHTHALENE	1000	2200	
C455	4-CHLOROANILINE	1000 U		
C460	HEXACHLOROBUTADIENE	1000	50000	*
C465	P-CHLORO-M-CRESOL	1000 U		
C470	2-METHYLNAPHTHALENE	1000	750	J
C510	HEXACHLOROCYCLOPENTADIENE	1000 U		
C515	2,4,6-TRICHLOROPHENOL	1000 U		
C520	2,4,5-TRICHLOROPHENOL	5000 U		
C525	2-CHLORONAPHTHALENE	1000 U		
C530	2-NITROANILINE	5000 U		
C535	DIMETHYL PHTHALATE	1000 U		
C540	ACENAPHTHYLENE	1000	50	J
C545	3-NITROANILINE	5000 U		
C550	ACENAPHTHENE	1000	560	J
C555	2,4-DINITROPHENOL	5000 U		
C560	4-NITROPHENOL	5000 U		
C565	DIBENZOFURAN	1000	230	J
C570	2,4-DINITROTOLUENE	1000 U		
C573	2,6-DINITROTOLUENE	1000 U		

CHESTER LABNET DC #---- 8

SAMPLE NUMBER: S04J000203

SEMIVOLATILE ORGANICS ANALYSIS DATA SHEET, CONTINUED

DATAFILE: 4U12159C03

	COMPOUND	DETECTION LIMIT (MILLIGRAMS / KG)	AMOUNT FOUND
C580	DIETHYL PHTHALATE	1000 U	
C585	4-CHLOROPHENYL PHENYL ETHER	1000 U	
C590	FLUORENE	1000	890 J
C595	4-NITROANILINE	5000 U	
C610	4,6-DINITRO-2-METHYLPHENOL	5000 U	
C615	N-NITROSODIPHENYLAMINE	1000 U	
C625	4-BROMOPHENYL PHENYL ETHER	1000 U	
C630	HEXACHLOROBENZENE	1000	900 J
C635	PENTACHLOROPHENOL	5000 U	
C640	PHENANTHRENE	1000	1600
C645	ANTHRACENE	1000	74 J
C650	DI-N-BUTYL PHTHALATE	1000 U	
C655	FLUORANTHENE	1000	290 J
C715	PYRENE	1000	390 J
C720	BUTYL BENZYL PHTHALATE	1000 U	
C725	3,3'-DICHLOROBENZIDINE	2000 U	
C730	BENZO(A)ANTHRACENE	1000	74 J
C745	BIS(2-ETHYLHEXYL)PHTHALATE	1000 U	
C740	CHRYSENE	1000	71 J
C760	DI-N-OCTYL PHTHALATE	1000 U	
C765	BENZO(B)FLUORANTHENE	1000 U	
C770	BENZO(K)FLUORANTHENE	1000 U	
C775	BENZO(A)PYRENE	1000 U	
C780	INDENO(1,2,3-CD)PYRENE	1000 U	
C785	DIBENZO(A,H)ANTHRACENE	1000 U	
C790	BENZO(GHI)PERYLENE	1000 U	

U = UNDETECTED AT THE LISTED DETECTION LIMIT
J = COMPOUND IS PRESENT, BUT BELOW THE LISTED DETECTION LIMIT
* = AMOUNT TAKEN FROM 1:1000 CORRECTION FACTOR RUN

SAMPLE: S04J000203

ORGANICS ANALYSIS DATA SHEET - PAGE 5

LABORATORY NAME: CHESTER LABNET CASE NO.: --

ANALYST: JZ DATAFILE: 4U12159C03

B. TENTATIVELY IDENTIFIED COMPOUNDS

CAS #	SEMIVOLATILE COMPOUND NAMES	SCAN#	PURITY	AMOUNT
				MG/
76-01-7	ETHANE, PENTACHLORO-	308	901	350
	CHLORINATED HYDROCARBON COMPOUND	450		390
	CHLORINATED HYDROCARBON COMPOUND	488		270
	CHLORINATED HYDROCARBON COMPOUND	493		700
	CHLORINATED HYDROCARBON COMPOUND	524		2300
	CHLORINATED HYDROCARBON COMPOUND	533		1400
90-12-0	NAPHTHALENE, 1-METHYL-	664	942	510
	BENZENE, TETRACHLORO	673		230
4994-16-5	BENZENE, 3-CYCLOHEXEN-1-YL-	682	941	520
	POLYAROMATIC HYDROCARBON	721		450
608-93-5	BENZENE, PENTACHLORO-	820	914	570
	UNKNOWN-DOESN'T MATCH ANY LIBRARY SPECTRA	890		4500

ESTIMATED VALUE - A 1:1 RESPONSE FACTOR IS ASSUMED

Chester LabNet - HOUSTON

Reported on : 13-JAN-1994

Client Name	: FRENCH LIMITED	Work Order	: H93-12.159
Sample ID	: CBP0110-040	Date Collected	: 23-NOV-1993
Sample Name	: H93-12.159-003 1/50	Matrix	: SOIL
Project No.	: S04J	Date Received	: 17-DEC-1993
Client ID	: S04J0002 03	Date Extracted	: 28-DEC-1993
		Checked by	: MJM

Organic Analysis Data Sheet
Compounds Analysis by SW846 Method 8080

Date Analyzed : 11-JAN-1994 19:04 Dilution Factor : 50.000
Analyzed by : 8388656

Cas #	Compound	Detection Limits	Detected Conc. ug/kg	
12674-11-2	AROCLOR-1016	25000	25000	U
11104-28-2	AROCLOR-1221	25000	25000	U
11141-16-5	AROCLOR-1232	25000	25000	U
53469-21-9	AROCLOR-1242	25000	25000	U
12672-29-6	AROCLOR-1248	25000	25000	U
11097-69-1	AROCLOR-1254	25000	25000	U
11096-82-5	AROCLOR-1260	25000	25000	U
	TOTAL PCBS *	25000	25000	U

* = Total PCBs calculated as found AR 1242.
U = Undetected at the Listed Detection Limit .
J = Compound is present, but below the Detection Limit.
B = Compound is also found in Blank.